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FOR
HORTICULTURAL SCIENCE

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OFFICERS AND COMMITTEES FOR 1943

President....................J. C. MILLER
Vice-President....................W. P. TUFTS
Sectional Chairmen:..........R. D. ANTHONY, F. S. JAMISON, and E. C. VOLZ
Secretary-Treasurer....................H. B. TUKEY

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J. H. MACGILLIVRAY, *Vice-Chairman* C. L. VINCENT, *Secretary*

GREAT PLAINS SECTION (for 1941–42, elected August, 1941)

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P. D. HARGRAVE, *Vice-Chairman* M. F. BABB, *Secretary*

SOUTHERN SECTION (for 1942–43, elected February, 1942)

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A.A.A.S. COUNCIL

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L. G. SCHERMERHORN
H. L. CRANE

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PHILIP BRIERLEY (1943)
M. B. DAVIS (1944)
G. F. POTTER (1945)

LOCAL ARRANGEMENTS

R. B. FARNHAM, *Chairman*

NATIONAL RESEARCH COUNCIL

E. C. AUCHTER

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

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*As revised and adopted at the Philadelphia meeting, January 1, 1941.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SECRETARY'S REPORT

Plans for the thirty-ninth annual meeting of the Society to have been held at Hunter College, New York City, December 29, 30 and 31, 1942 were well under way when word was received from the American Association for the Advancement of Science, dated November 27th, advising that the Office of Defense Transportation had informed the American Association for the Advancement of Science under date of November 25th "This will relate to your conversation with this office today regarding the meeting of your society, which was originally scheduled to be held late next month.

"In all fairness to you, your membership and the transportation industry, there is only one request we can consistently make, namely, that your meeting originally scheduled for the holiday period be postponed. We make this request with the full realization that there are many important discussions included in your program, but the general transportation situation is such that many organizations similar to your own must sacrifice their meetings in the interest of the war effort."

In compliance with this request from the Office of Defense Transportation, the Executive Committee of the American Association for the Advancement of Science voted to postpone the New York meeting.

In accordance with this statement, recognizing that it would be both futile and unwise for the American Society for Horticultural Science to hold a meeting in New York City on December 29, 30, and 31, as originally planned, the Executive Committee, on December 4th, voted to postpone the New York City meeting indefinitely.

An excellent program had been arranged by Dr. L. C. Chadwick, Chairman of the Program Committee, and was in the process of being printed at the time the meeting was cancelled. Excellent local arrangements had been prepared by Dr. R. B. Farnham. It was regretted that circumstances prevented the enjoyment of both the program and the arrangements which had been so carefully prepared, but no other course was open to the Society.

The Executive Committee of the American Society for Horticultural Science is authorized by the By-Laws of the Society "to act for the Society in the interim between annual meetings"......and......"fix the date for the annual meeting". Accordingly, after having voted to postpone the 1942 meeting indefinitely, the Executive Committee voted to publish the Proceedings of the Society and to continue other activities of the organization insofar as consistent with the national emergency.

The program of the New York City meeting was circularized among the members, together with a call for manuscripts to be sent promptly to the Secretary's Office for publication. Although the procedure of other years has called for the submission of a title to the annual meeting of the Society or to one of the sectional meetings before it can be accepted for publication, it has seemed only fair in view of the cancellation of the meeting of the Southern Section and the possible cancellation of other meetings to permit the submitting of manuscripts to the Society regardless of whether meetings were held. In practical application this means that each member is entitled to four pages in the Proceedings during the calendar year, without charge, payment however being made for extra pages and for cuts. Plans have been made for two volumes of the Proceedings as in former years, depending, of course, upon circumstances.

The Executive Committee voted that the Society membership be asked to approve or disapprove the suggestion that the officers of the Society for 1942 retain office until the regular annual meeting of 1943 or until the next annual meeting, whichever occurs first. A very high percentage of the members replied (over 70 per cent), all approving this suggestion.

Many suggestions have been received from members regarding the activities of the Society and regarding meetings. The concensus of opinion seems to be that the organization should attend to first things first, namely, the publication of the Proceedings, and the holding of general and sectional meetings if and when possible. There seems no general disposition for other than strong compliance with the suggestions from the Office of Defense Transportation asking that large group meetings be not held. Suggestions from the members are in the main in favor of small regional meetings, followed perhaps by a skeleton organization or business meeting.

Membership in the Society numbered 736, in good standing in December, 1942, representing a gain of 21 from last year. Loss in foreign membership has been more than made up by the increase in new members in the United States, due largely to the active work of the Committee on Sectional Groups and Membership with Dr. R. L. McMunn as chairman. The money received from dues during 1942 was $3910.00, an increase of $105.90 from the previous year. The receipts from the sale of Proceedings was $1467.30, a gain of $149.92. Extra pages purchased by authors amounted to $854.55, a substantial increase of $468.35; and purchase of reprints and etchings amounted to $2,419.46, an increase of $552.24.

The general condition of the Society indicates a final small gain in membership in the year and an increase in income, which balances both the extra cost of printing two volumes of the Proceedings (1056 pages) and the extra cost of increased Society activities, such as printing and circularizing programs of sectional meetings of the Society. The cash on hand December 20, 1942, plus bills receivable amounts to $4596.70, as compared with $4517.83 in 1941, and $4715.20 in 1940. The figures indicate that the Society is on fairly even keel, but it is only by attention to economies and details of income that they can be maintained in this condition. While the Society has sufficient funds to carry on its activities and publish the Proceedings, it can be seen that it has no extra reserve, but rather is returning to its membership full value for the money received in dues. This policy is probably correct, and at least it is the will of the membership, but it does not build up any cash reserve for emergency. The Society really operates very similarly to a non-profit cooperative organization in which any benefits are returned to the entire membership.

TREASURER'S REPORT

Receipts

Dues (1941–42)	$3,910.00		
Proceedings sold	1,467.30		
Extra pages purchased by authors	854.55		
Reprints and cuts purchased by authors	2,419.46		
J. T. Bregger (banquet ticket)	1.75		
		$8,653.06	
Interest on money in savings account		74.78	
Balance on hand December 20, 1941		3,193.10	
Bills receivable, outstanding accounts—			
Proceedings	$276.81		
Extra pages	323.00		
Reprints and cuts	589.90	1,189.71	
			$13,110.65

Expenditures

Expenses of Dallas, Texas meeting	$ 180.50
Printing Proceedings, vols. 40 and 41	5,264.05
Reprints, vols. 40 and 41	902.34
Programs, envelopes, letterheads, labels, etc	183.85
Halftones and etchings for Proceedings, vols. 40 and 41	768.63
Secretary's office, including clerical assistance	485.12
Postage and express, office and shipping Proceedings	373.60
Stamped envelopes	85.32
Proceedings purchased for resale	111.00
Addressing machine	123.66

Bond	30.00		
Exchange on checks during 1942	5.88		
Total expenditures		$8,513.95	
On hand December 28, 1942		3,406.99	
Bills receivable		1,189.71	
			$13,110.65

This is to certify that we have examined the books of the Treasurer of this Society and have found them in good order.

Auditing Committee,
G. J. RALEIGH, *Chairman*
J. W. WELLINGTON

THE VAUGHAN RESEARCH AWARD IN HORTICULTURE

I. REGULATIONS

Through the generosity of Mr. L. H. Vaughan of Vaughan's Seed Stores, Chicago, the American Society for Horticultural Science is able to offer two awards of $500 each for the best papers presented before the Society. One award is to be made in the field of Floriculture and one in Vegetable Crops. It is expected that these awards will be made for at least three years. These will be known as the Vaughan Research Awards. The following regulations governing these awards have been adopted:

1. The winning papers must be presented by members of the Society to the Annual Meeting or any one of the recognized Sectional Meetings and published in the Proceedings. Papers by two or more authors will be considered as units. Presentation need not be in person.
2. One award of $500 will be made for a paper reporting research in Floriculture and one of $500 for one in Vegetable Crops, provided that if no worthy paper in one of these fields is presented, one of the awards may be made in some other field of Horticulture. If no worthy paper appears, no award will be made.
3. Preference will be given to papers that present new discoveries in these fields, showing promise of commercial importance or practical applications.
4. All papers presented during a space of one year following December 1 of each year will be considered for the awards of that year. The winners will be announced at the Annual Meeting in the following year. Awards will be made at the 1942 meeting (provided worthy papers appear) for two papers that have been presented and published in the Proceedings between December 1, 1941 and November 30, 1942.
5. In making the awards, due consideration will be given to the age, experience and record in research work of the authors. Preference will be given to papers by authors under 35 years of age.
6. Judging the papers will be on the basis of (1) originality, (2) soundness, (3) accuracy, (4) clearness and conciseness of presentation and (5) value of the work, especially in its practical applications.
7. These regulations and the Committee Procedure following are to be considered as tentative. They will be adhered to, if possible, for this year.

II. COMMITTEE PROCEDURE

1. As soon as possible after the publication of the Proceedings in each year, each member of the Committee will submit to the chairman lists of what he considers to be the five most worthy papers in each field.
2. The chairman will immediately prepare a list of all papers suggested and forward a copy to each Committee member together with a blank ballot. Each Committee member shall rank what he considers to be the best four papers in the list in each field and forward his ballot to the chairman.

3. The chairman will report back to the Committee members the results of this ballot. He shall assign a weight of 6 for the paper ranked first, 4 to the second, 2 to the third and 1 to the paper ranked fourth.

4. Each Committee member shall then mail to the chairman his assent to the result of the ballot or his dissent, giving his reasons therefor, which he shall also send to each Committee member.

5. Each Committee member shall then inform the chairman of his opinion on the question at issue. If further correspondence does not result in a unanimous decision as to which are the winning papers, a majority vote shall prevail.

6. If necessary and possible, a meeting of the Committee may be held immediately prior to the Annual Meeting of the Society for discussion and final choice of the winning papers.

7. No member of the Committee shall divulge the discussions, but he may receive and even solicit the opinions of his colleagues on the worth of certain papers.

8. The final decision shall be made public at the Annual Banquet or at such other time as may seem proper.

III. Committee Organization

1. The committee shall consist of the president and the four immediate past presidents, of whom the senior in office shall be chairman.

The Vaughan Research Award in Horticulture in 1942 was made to Dr. O. A. Lorenz and Dr. J. E. Knott of the University of California, Davis, California, for their paper "Studies of Gray-Wall of Tomato" Proceedings of the American Society for Horticultural Science 40: 445–454. 1942.

Committee, V. R. Boswell
L. H. MacDaniels
F. C. Bradford
J. C. Miller
J. K. Shaw, *Chairman*

COMMITTEE ON NITROGEN UTILIZATION

A Committee on Nitrogen Utilization was appointed by the President as follows: Dr. A. F. Camp, Dr. J. H. Gourley, Dr. E. L. Proebsting, Dr. H. C. Thompson, and Dr. H. H. Zimmerley, Chairman.

Effect of Heavy Mulch in an Apple Orchard Upon Several Soil Constituents and the Mineral Content of Foliage and Fruit

By I. W. WANDER and J. H. GOURLEY, *Ohio Experiment Station, Wooster, Ohio*

PREVIOUS investigations (10) showed larger amounts of available potassium beneath old straw mulches than on comparable plots under cultivation with cover crops.

The study here reported was made to extend these observations to include other fertility constituents and their combined effect upon the mineral content of leaves and fruit grown in the two systems of culture, namely (a) mulch and (b) cultivation with cover crops. Soil components studied were total exchangeable bases, exchangeable potassium, calcium, magnesium, readily available phosphorus, water-soluble boron, per cent of organic matter, and pH. Leaf and fruit studies included the percentage on a dry weight basis of potassium, calcium, magnesium, phosphorus, boron, and total ash.

TREATMENTS

All soil, leaf, and fruit samples were taken from Orchard C of the Ohio Agricultural Experiment Station, Wooster, Ohio. This orchard located on Wooster silt loam, was planted in 1915 and divided into two blocks. One block has been continuously cultivated and seeded to both summer and winter cover crops. The other block was sodded down and the mulch system begun immediately after planting. The mulch has consisted of wheat straw applied in a ring beneath the drip of the branches at the rate of 150 to 200 pounds per tree per year. No commercial fertilizer or manure had been used on either block from which samples were obtained. Growth and yield of trees under both systems of culture have been exceptionally good, but the mulch system is giving somewhat superior results at present (5).

SAMPLING METHODS

Soil samples were obtained with a soil tube to a depth of 24 inches. Ten samples were taken beneath each tree, divided into 6-inch levels, and composited for a total of four samples at 6-inch levels from under each tree. The area beneath four trees, two in cultivation and two in mulch, was thus sampled. All samples were air-dried, crushed with a rolling pin, screened with a 2-millimeter sieve, and stored in glass jars with tight-fitting lids.

Leaf samples were taken from the same four trees. Two hundred leaves were taken from each tree at the mid-portion of the terminal growth. The leaves were dried in a ventilated oven at 70 degrees C, ground in a Wiley mill, redried, and stored in glass containers. The leaf samples obtained represented the varieties Stayman Winesap and Delicious. Both soil and leaf samples were obtained September 20, 1940.

Fruit samples were obtained from the Stayman Winesap trees October 20, 1940 and placed in storage until ready for market. When removed from storage, the apples were quartered, cored, and sliced into thin sections. The slices and cores were dried at 70 degrees C for 48 hours in a forced-draft oven, then quickly ground, mixed, and replaced in the oven for 24 hours. The ground samples were stored in tightly sealed glass jars until analyzed.

ANALYTICAL PROCEDURES

Soil:—The total exchangeable bases were determined by the method of Bray and Wilhite (3). In this method, which uses an automatic leaching device, the exchangeable bases of the soil are replaced by the ammonium iron supplied by a neutral ammonium acetate solution. Duplicate 20-gram samples were leached, and after the total exchangeable bases were determined, were combined, evaporated, and made up to 100 milliliters. Aliquots of these solutions were taken for the potassium, calcium, and magnesium determinations.

Potassium was determined by the method of Brown, Robinson, and Browning (4), which utilizes ceric sulfate to oxidize the precipitated potassium-sodium cobaltinitrite.

Calcium was determined according to the micro method described in the fourth edition of the Association of Official Agricultural Chemists Official and Tentative Methods (1).

The magnesium determination was carried out by a method similar to that of Kramer and Tisdell (7). The magnesium was precipitated by the standard method, the precipitate recovered by centrifuging, and the magnesium determined indirectly from the amount of phosphorus in the precipitate. Zinzadze's method was used for the determination of the phosphorus in the precipitate (11).

Readily available phosphorus was determined by the method of Truog (8).

Boron determinations were made by using the quinalizarin reaction as described by Berger and Truog (2).

Per cent organic matter was determined by the Walkley-Black method (9), modified by the use of orthophenanthroline as indicator. pH determinations were made by the glass electrode method.

Leaf and Fruit Tissue:—Two grams of leaf and 4 grams of fruit tissue were wet-ashed with nitric and perchloric acids. The resulting salts were dissolved and made to 250 milliliters. After the dehydrated silica had settled out, aliquots of these solutions were taken for the potassium, calcium, magnesium, and phosphorus determinations. The potassium, calcium, magnesium, and boron were determined by methods described under analytical procedures for soils. Phosphorus determinations were made according to the method outlined by Zinzadze (11).

Crude ash was determined by ashing a weighed portion of the dried material to constant weight in a muffle at 600 C.

RESULTS

Soil:—The results of the soil studies are presented in Figs. 1 to 8.

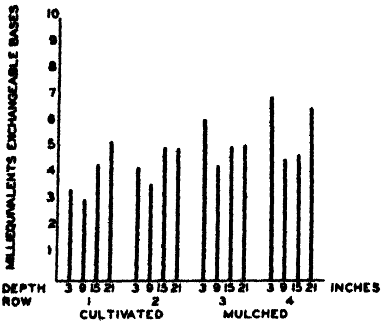

FIG. 1

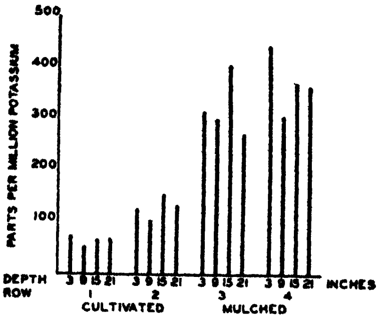

FIG. 2

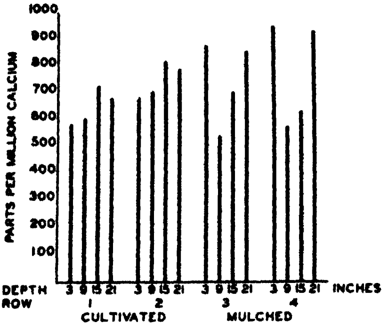

FIG. 3

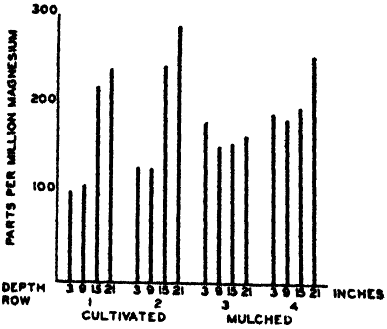

FIG. 4

FIGS. 1–4. Milliequivalents of exchangeable bases (Fig. 1), exchangeable potassium (Fig. 2), exchangeable calcium (Fig. 3), and exchangeable magnesium (Fig. 4).

The depth in inches referred to is the mean depth; for example the 0- to 6-inch depth is designated as 3 inches; the 6- to 12-inch depth as 9 inches, and so on. Rows 1 and 2 are both cultivated, and the results from them therefore check each other, and also show the variation which may be expected within the same treatment. The same is true of rows 3 and 4, which are mulched. All results expressed are the average of duplicate determinations which fall within the range of experimental error.

The milliequivalents of exchangeable bases (Fig. 1) have been increased most noticeably in the 0- to 6-inch depth and to some extent in the 6- to 12-inch depth under mulch. Beyond that depth no effect due to treatment was evident.

Exchangeable potassium has been considerably increased in all levels to which samples were taken under mulch as compared with cultivation (Fig. 2). This observation is in agreement with a previous report (10).

The surface beneath the mulch contains considerably more exchangeable calcium (Fig. 3) than the same depth under cultivation. There is also apparently some accumulation in the lowest depth sampled under mulch, but a smaller amount in the medium depths, 6 to 12 and 12 to 18 inches, as compared with cultivation.

The exchangeable magnesium (Fig. 4) presents a peculiar picture; highest values found were the two lowest depths under cultivation. There has been some increase, however, in the two upper depths under mulch as compared with cultivation.

There has been a very definite increase in the readily available phosphorus (Fig. 5) to be found in the surface 6-inch depth under mulch, and some influence extends to samples in the 6- to 12-inch level.

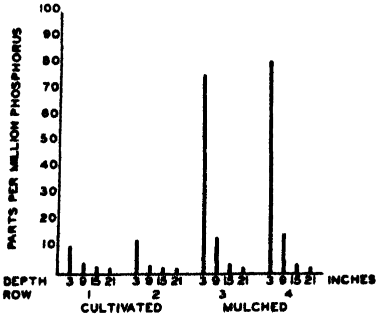

FIG. 5

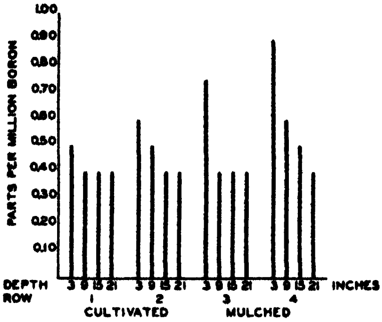

FIG. 6

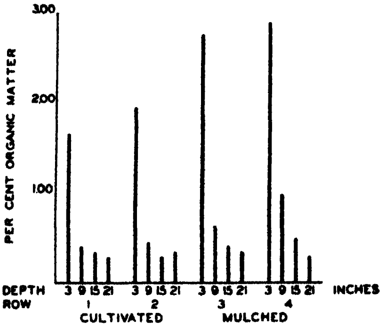

FIG. 7

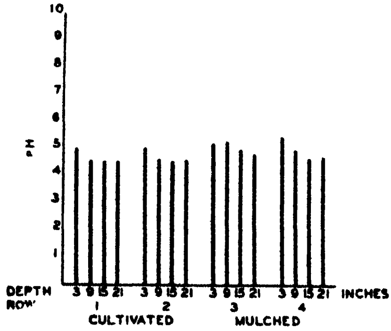

FIG. 8

FIGS. 5–8. Parts per million of readily available phosphorus (Fig. 5), of available boron (Fig. 6), percentage of organic matter (Fig. 7), and pH (Fig. 8).

The available or water-soluble boron (Fig. 6) has been increased in the area immediately below the mulch. There is apparently little, if any, change in the lower depths due to either cultural system.

The percentage of organic matter (Fig. 7) has been increased in the top layer of soil under the mulch, and a small influence was found in the 6- to 12-inch level.

The pH (Fig. 8) of the soil has been increased slightly under mulch. The effect seems to be a small one over a period of years.

Leaf Tissue:—The leaf sample from row 1 (cultivated) is compared with the sample from row 4 (mulched). Both samples are Stayman Winesap. The sample from row 2 (cultivated) is compared with the sample from row 3 (mulched); both are Delicious leaves.

The analytical data for the leaves are given in Table I. From these

TABLE I—LEAF TISSUE ANALYSIS

Treatment	Per Cent K	Per Cent Ca	Per Cent Mg	Per Cent P	Per Cent B	Per Cent Ash
			Stayman Winesap			
Cultivation	1.23	1.82	0.420	0.108	0.0030	6.46
Mulch	1.54	1.36	0.350	0.110	0.0036	6.12
			Delicious			
Cultivation	1.56	1.09	0.282	0.108	0.0044	5.90
Mulch	2.32	1.12	0.262	0.129	0.0048	6.78

results it can be seen that potassium especially, and phosphorus and boron to some extent, have been increased in the Stayman Winesap leaves taken from the tree under mulch. At the same time, the calcium and magnesium contents of these leaves have decreased. The crude ash content has decreased slightly in Stayman leaf samples from mulch as compared with cultivation.

The elements determined have been increased in the Delicious leaves grown in mulch, except magnesium, which has decreased slightly. The potassium and phosphorus contents have been particularly increased. The magnesium content of Delicious leaves is lower than that of Stayman Winesap leaves regardless of treatment. The crude ash of Delicious leaves from the mulch treatments has increased considerably.

Apple Flesh and Cores:—Results are given for the flesh and cores of Stayman Winesap apples grown under the two systems of culture (Table II). The flesh and cores both reflect the same variations in elemental content due to treatment as do the leaves, except for magnesium, which is somewhat increased in fruit from mulched trees. The crude ash content of the flesh and cores has been increased by the mulch system. Since a large portion of the ash of apple fruit is potassium and phosphorus, their increase in the fruit grown in mulch is reflected in the increase in crude ash. The effect of an increase of potassium upon the ash content of fruit has been noted in results from fertilizer experiments (6).

TABLE II—FRUIT ANALYSIS

Treatment	Per Cent K	Per Cent Ca	Per Cent Mg	Per Cent P	Per Cent B	Per Cent Ash
			Stayman Winesap—Flesh			
Cultivation	0.72	0.042	0.037	0.044	0.0018	1.47
Mulch	0.97	0.039	0.044	0.062	0.0018	2.12
			Stayman Winesap—Core			
Cultivation	1.09	0.136	0.084	0.134	0.0032	2.41
Mulch	1.33	0.114	0.097	0.142	0.0032	3.02

SUMMARY

Data presented show the effect of a heavy mulch system of culture upon the concentration and approximate position in an orchard soil of the elements potassium, calcium, magnesium, phosphorus, and boron

as compared with a system of clean cultivation with winter and summer cover crops. These data are supplemented with determinations on total exchangeable bases, per cent of organic matter, and soil reaction under the two treatments.

Data are also presented for the determination of potassium, calcium, magnesium, phosphorus, boron, and crude ash in the leaves and fruit obtained from trees grown under both systems of culture.

It was found that all the elements investigated had been increased in the soil beneath a heavy mulch as compared with adjacent land under cultivation. Potassium was considerably increased under mulch at all depths sampled. A smaller effect was noted on calcium and magnesium. The increases in phosphorus, boron, and organic matter were confined to the area just beneath the mulch.

The potassium and phosphorus contents of both the leaves and fruit have been increased by mulching. The calcium and magnesium contents of the leaves were decreased by mulching. Calcium was the only element of those studied that was reduced in the flesh and cores of fruit from mulch plots; potassium, phosphorus, and magnesium were increased. Boron was increased slightly in the leaves of the mulched trees but remained the same in the fruit from both treatments.

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Further Results on the Effect of Different Mulching and Fertilizer Treatments Upon the Potassium Content of Apple Leaves[1]

By CLARENCE E. BAKER, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

THE potassium content of leaves from terminal shoots of Grimes apple trees under different systems of soil management and fertilizer treatments has been previously reported for the 1939 and 1940 seasons (1). The outstanding feature of these studies was the high K content of leaves from trees grown under a mulch of straw or strawy manure in comparison with leaves from trees in cultivation or sod. Even when K or combinations of P, K and N were applied to trees in cultivation, little increase in the K content of leaves from terminal shoots could be found over trees receiving no fertilizer. Regardless of fertilizer treatment leaves from trees in cultivation or sod showed less K than leaves from trees grown under a mulch of straw or manure. Leaves from trees mulched with glass wool, where no nitrogen fertilizer was applied, generally showed more K than leaves from cultivated trees in any fertilizer treatment or than in leaves from trees in sod.

The P and K applications were repeated in the spring of 1942. Ten pounds per tree of KCl was applied on the soil beneath the spread of the branches and disced in. Trees in the P treatments received 15 pounds of superphosphate in 15 auger holes 18 inches deep. This was the first P or K fertilizers these trees had received since the original application in the spring of 1938. The manure mulch on plots A-E and A-W was replenished in the spring of 1941. The straw mulched trees in plot E-S each were given two bales additional in the spring of 1942.

The fruit crop of 1941 was heavy on all the plots in this series. The trees in sod and the several mulched treatments all bore good sized, high quality fruit, following a moderate thinning. The fruit on the cultivated trees, regardless of fertilizer treatment, was small and of very poor quality. The crop was light in 1942, and, with the exception of the manure mulched trees in A-E and A-W, none of the trees in these plots had more than a few apples. Trees in plot A-E averaged approximately 6.5 bushels per tree and trees in plot A-W, 16 bushels. No nitrogen fertilizer was applied to either plot A-E or A-W in 1941 or 1942. The straw mulched trees in E-S bore practically no fruit in 1942.

The results of the leaf analyses for 1941 and 1942 are shown in Table I. There is no consistently higher level of K shown by the trees that bore practically no crop in 1942 in comparison with the 1941 season when all trees fruited heavily. In the case of plot E-S, the higher K content of the leaves in 1942 in comparison with 1941 may be because additional K was supplied to the tree by the new straw added early in 1942. In the case of sod plots C-E and C-W the K level of 1941, when the trees fruited heavily, was essentially the same

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[1] Journal Paper No. 72, Purdue University Agricultural Experiment Station.

TABLE I—POTASSIUM IN PER CENT OF DRY WEIGHT OF LEAVES OF GRIMES APPLE TREES UNDER DIFFERENT SYSTEMS OF SOIL MANAGEMENT (LAFAYETTE, INDIANA)

Plot	Fertilizer Treatment*	Per Cent K (1941)		Per Cent K (1942)		
		Jun 5	July 17	May 25	July 16	Aug 25
Cultivation						
B-7-E	O	1.55	1.38	1.33	1.49	1.35
B-7-W	N	1.02	1.04	1.14	0.79	0.57
B-8-E	P K	1.46	1.31	1.27	1.30	1.29
B-8-W	P K N	1.20	1.12	1.13	1.16	1.05
B-9-E	P	1.73	1.86	1.43	1.65	1.70
B-9-W	P N	1.24	1.03	1.12	1.15	1.10
B-10-E	K	1.74	1.47	1.50	1.53	1.57
B-10-W	K N	1.52	1.25	1.56	1.54	1.45
*Glass Wool Mulch***						
B-11-E	O	1.89	1.81	1.73	1.98	1.95
B-11-W	N	1.37	1.19	1.40	1.28	1.33
Sod						
C-E	N	1.59	1.54	1.47	1.57	1.59
C-W	N	1.49	1.44	1.44	1.49	1.59
Strawy Manure Mulch†						
A-E	O	1.97	1.76	2.24	1.96	1.87
A-W	O	1.89	1.68	2.18	1.67	1.46
Sod‡						
E-G	N	1.52	1.46	1.81	1.73	1.74
Straw Mulch§						
E-S	N	1.89	1.59	2.06	2.04	2.01

*N = Annual spring applications of sulphate of ammonia; P = 15 pounds superphosphate per tree applied in 15 auger holes 18 inches deep, 1 pound per hole, April, 1938 and April, 1942; K = 10 pounds KCl per tree on surface beneath branches and disced in, April, 1938 and April, 1942; O = no chemical fertilizer used.

**An inorganic mulch of glass wool 3 inches thick 20 by 20 feet square applied beneath branches. Area between trees in bluegrass sod. This treatment started in April, 1938, with cultivation previous to that time.

†Strawy manure mulch since fall of 1934, previously cultivated.

‡Cultivated until spring of 1937. Area between trees then seeded to bluegrass.

§Straw mulch since spring of 1938.

as in 1942, when no fruit was produced. The manure mulched trees in A-E and A-W, bearing fruit both years showed a slightly higher K level during 1942 than during 1941. The effect of a crop on reducing the K content of leaves where bearing and non-bearing (fruit removed) prune trees were compared during the same season has been reported (2).

There is yet little indication that the K applied to the soil in the KCl fertilizer is reaching the leaves. Leaves from trees in the K treatments or from those receiving combinations of P K or N P K generally show less K than leaves from trees in sod and much less than from trees under a straw or manure mulch. Often the cultivated trees that received no fertilizer show more K in the leaves than trees to which KCl was applied. There is very little available K_2O in the upper 8 inches of the cultivated soil where no KCl was applied.

The lower K content of leaves from trees where N was used alone or in combination with P or K, or when N was used with the glass wool mulch, again is quite consistent during the 1941 and 1942 seasons.

Miscellaneous Mulching Materials

In another block of trees, adjoining the orchard where the plots described in Table I are located, a test of various mulching materials is being conducted. These studies were started in 1939 on trees that were then 17 years old and had been in sod since 1930, with no nitrogen fertilizer since 1933. The trees had been in an extremely devitalized condition since 1936.

Various organic and inorganic mulches, as listed in Table II, were added late in the summer of 1939, with the exception of the paper clippings which were applied a year later. All trees except those to which manure or tobacco mulches were applied received five pounds of sulphate of ammonia in the spring of 1940. After this, no nitrogen fertilizer was applied to the mulched trees, except to the sawdust mulched trees in the spring of 1942. The omission of the nitrogen on this treatment in 1941 resulted in an obvious nitrogen shortage. Even the 5 pounds of sulphate of ammonia applied in 1942 did not entirely overcome this deficiency. All of the other mulched trees appeared to have sufficient nitrogen during both the 1941 and the 1942 season. The original tobacco mulch decomposed rapidly and was replenished in August, 1940. A second application of manure was made to the trees in this treatment in the spring of 1941. Trees in sod with an annual application of sulphate of ammonia are used as checks.

TABLE II—Potassium in Per Cent of Dry Weight of Leaves of Apple Trees in Sod and Under Different Mulches

Plot	Treatment	Sulphate of Ammonia (Lbs Per Tree)			Per Cent K (1941)		Per Cent K (1942)		
		1940	1941	1942	May 26	July 22	May 28	July 21	Aug 26
				Grimes					
N 1	Sod	5	5	5	1.49	1.09	1.29	1.29	1.25
N-2	Tobacco mulch	0	0	0	2.39	1.72	2.26	2.09	1.98
N-3	Straw mulch	5	0	0	2.08	1.56	1.83	1.92	2.15
N-4	Cinder mulch	5	0	0	2.12	1.89	2.05	2.22	2.28
M-1	Sod	5	5	5	1.63	1.25	1.29	1.02	0.98
M-2	Glass wool-mulch	5	0	0	2.57	1.72	2.14	2.26	2.24
M-3	Straw mulch	5	0	0	2.62	1.95	2.10	2.35	2.32
S-1	Sod	5	5	5	1.95	1.49	1.57	1.27	1.24
S-2	Straw mulch	5	0	0	2.52	1.62	2.11	1.94	1.87
S 3	Paper mulch	5	0	0	2.61	1.56	2.26	2.21	1.93
S-4	Manure mulch	0	0	0	2.21	1.66	2.04	1.72	1.54
				Rome					
M 1	Sod	5	5	5	1.37	1.27	1.24	1.02	0.96
M-2	Sawdust mulch	5	0	5	2.09	2.05	1.91	1.96	1.85
M 3	Straw mulch	5	0	0	1.86	1.62	1.76	1.54	1.70

The Grimes trees bore heavily in 1941 but had little fruit in 1942. The Rome trees bore moderate crops both years.

The high K value of leaves from trees in the orchard previously discussed, that were mulched with glass wool, prompted a study of the conditions existing in the trees in these various mulch treatments.

While there is considerable difference in the amount of K in the leaves from the trees mulched with different materials it is interesting that all the mulches used caused an increase in the K content of the leaves, as compared with the trees in sod.

The inorganic materials, cinders and glass wool, produced practically the same increases as the organic materials, such as straw, manure, sawdust and tobacco, that are known to have considerable quantities of soluble K. One of several reasons suggested for the higher K content of the leaves from the straw and manure mulched trees in the original study was assumed to be the utilization of soluble K from the mulching material. Another possibility suggested was the more efficient exploration of the surface soil by the increased number of feeding roots resulting from the use of a mulch. As N tends to reduce the K content of leaves, it also is likely that mulching materials having a high C/N ratio may increase the K content of leaves to a greater extent than materials having a low C/N ratio. The role of soil moisture also is important. The soil under mulches is less subject to drying out and for this reason the K probably remains in a more constantly available condition than in soils that become extremely dry.

While either or both of the first two above suggestions might apply to an organic mulch, known to contain considerable quantities of water soluble K and other nutrients, the first would not apply to a chemically inert mulch such as glass wool and cinders. Cinders undoubtedly contain chemical compounds that may be washed into the soil. Concentrated leachings from cinders in the laboratory, however, showed no K. The leachings from paper clippings also gave no test for K.

All of the mulching materials used greatly stimulated the growth of fibrous roots in the upper part of the surface soil. In the case of manure, straw and sawdust the heavy development of new fibrous roots extended well up into the mulch itself. With glass wool, cinders and paper the greatest concentration of small roots was in the surface soil just below the mulch or on top of the soil, between the soil and the mulch. The total fibrous root development under the glass wool, cinders and paper was less extensive than in the case of the manure, straw and sawdust mulches.

SUMMARY

It would appear from these studies that the higher K content of leaves from trees mulched with inorganic materials may result from (a) some physical factors that make the K present in the soil more readily available or, (b) that conditions are more favorable for the growth of feeding roots in the surface soil area which makes possible a greater intake of K because of the larger volume of soil explored by the feeding roots. An organic mulch may, in addition, increase the supply of readily available K through the leaching caused by rains, or by the decomposition of the mulching material where it is in contact with the soil.

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Influence of Sod and Other Factors Upon the Distribution of Small Tung Roots in Ruston Sandy Loam[1]

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THE purpose of this paper is to report on the influence of sod and other factors upon the distribution of small tung roots in Ruston sandy loam. A number of factors may influence the growth and distribution of roots in the soil. Among these are: heredity, moisture, nutrition, aeration, temperature, toxic substances, root stimulants, soil texture, soil structure, root pruning, plant diseases and others. Weaver (6) and Miller (3) present general reviews of the literature.

MATERIALS AND METHODS

The trees were made available for study by Dr. J. C. Robert, former superintendent of the South Mississippi Branch Experiment Station at Poplarville, Mississippi. None of the trees reported in this paper were fertilized at any time. The study was made in 1941 and 1942.

Two lots of trees were studied, one planted in 1936 and the other in 1934. In the test started in 1936 the trees were planted directly in sod and in cultivated soil. The trees planted in sod were never cultivated during the experiment, while the trees that were cultivated were disced about two times a year. In the test started in 1934 all of the trees were planted in cultivated soil and the whole lot was cultivated for 3 years. After 3 years, one group (sod) received no further cultivation, while the other group was cultivated as before.

Tung trees that were planted in sod (1936 series) grew slowly while trees that were cultivated grew well. Six-year-old trees grown in sod averaged 5 feet tall and had trunks about 3 inches in diameter, while cultivated trees were 12 feet tall and had trunks that were 5 inches in diameter. Practically no nuts were produced by the sod trees while the cultivated trees produced abundantly.

The cultivated trees of the 1934 series appeared to be larger and to have darker green foliage than trees that were in sod (cultivated for 3 years). There was little difference in the production of tung nuts on the two treatments for several years, but there were indications in 1941 and 1942 that the cultivated treatment was surpassing the sod treatment, especially in places where the soil was infertile.

The distribution of roots in the soil was studied in two different ways. In preliminary tests, large rectangular trenches were dug along one side of the trunks and the roots were exposed by working inward, using an ice pick and by washing with a power sprayer.

A need was felt for a more exact method of measuring the distribution of roots in the soil than was obtainable by the above procedure. A soil sampling method was used for obtaining the roots from a given volume of soil. The method consisted of taking graduated metal cylinders of known diameter and forcing these into the soil to the desired depths in order to obtain cores of soil. Successive samples of soil were removed from the same holes in order to obtain roots at different depths. The number of replications are indicated in the tables. The soil was washed through window screens, using a stream of water. The roots were picked off of the screens with forceps, cleaned further to remove any soil, dried, and separated into different sizes, and weighed. All of the small "feeder" roots reported in this paper were 1 millimeter in diameter or smaller when dry. Practically no roots passed through the window screen as was determined by passing the water and soil from some of the above washings through other screens of smaller mesh.

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In some cases a post hole digger was used for sampling the soil. With sufficient care, it was possible to obtain cores of soil of fairly uniform diameter. Since the diameter and length of the cores of soil were known it was possible to calculate the weight of roots in a given volume of soil. For convenience, the results were calculated as the dry weight of roots per 1,000 cubic inches of soil.

Soil air was determined using a method of analysis similar to that used by Boynton (1). The method consisted of permanently establishing air wells in the soil at different depths and sampling the soil air periodically by means of a portable gas analysis apparatus. A simple mercury suction pump was used in drawing the soil air from the wells through a copper tube to the gas analysis apparatus. The results were calculated as percentage of oxygen and carbon dioxide in the soil air.

Other methods that were used will be explained in conjunction with the presentation of the results.

Results and Discussion

Effect of Sod and Cultivated Conditions on Root Distribution:— In preliminary tests, studying the distribution of roots from a trench, it was observed that there were very few small "feeder" roots under continuous sod conditions (1936 series) except close to the large roots and near to the trunks, especially in the upper 2 inches of soil. There were very few small roots in the subsoil. The greatest depth to which a root was traced was 3 feet.

Under cultivated conditions (1936 series) small roots were very abundant in the upper black soil and very scarce in the tan or red subsoil. The small roots that were not destroyed by cultivation were sometimes matted even on top of the ground. In the subsoil the small roots became slowly but steadily less abundant with depth, the small roots being very scattered below 3 feet and almost non-existant below 6 feet. Exceptions to the slight "feeder" root development in the subsoil occurred in those regions where old tree roots from the original forest had either burned or rotted. In these restricted areas small tung roots were sometimes abundant. The large roots were mainly 18 inches deep or deeper. The greatest depth to which a root was traced was 8½ feet. On infertile Ruston sandy loam, especially in those places where soil erosion had been severe, small tung roots were scarce in both surface and subsoil.

Using a soil sampling method the following dry weights of small roots, 4 feet from the trunks, were found at different depths per 1000 cubic inches of soil under both sod and cultivated trees (1936 series): sod trees—0 to 6 inches, 4.49 grams; 6 to 14 inches, 0.38 grams; 14 to 22 inches, 0.26 grams; 22 to 36 inches, 0.09 grams: cultivated trees—0 to 6 inches, 11.81 grams; 6 to 14 inches, 2.09 grams; 14 to 22 inches, 1.24 grams; 22 to 36 inches, 0.38 gram. A marked difference is shown in the concentration of roots in the upper 6 inches and in the concentration below this depth under both cultivated and sod conditions.

Table I shows the distribution of small roots in the surface soil under sod and cultivated tung trees at different depths and distances from the trunks. The data show that a greater proportion of the roots were in the upper 2 inches of soil under sod than under cultivated trees. The greater percentage of very shallow roots under sod than under cultivated trees is due to the roots not being pruned by cultivation and by the top soil probably being richer because of the accumulation of dead leaves, and so on. A reduction in total root development is probably due to root competition with grass for water and nutrients. It is also possible that grass exerted a toxic influence upon tung trees similar to the effect of sod on orchard trees, as found by Pickering (4), or upon nitrification as found by Gourley and Shunk (2).

TABLE I—The Effect of Continuous Sod and Cultivation Upon Tung Tree Feeder Root* (0 to 1 Millimeter Diameter) Distribution (1941)

Distance From Trunks (Feet)	Depth (Inches)							
	0-2		2-4		4-6		Total	
	Sod (Gms)	Cult (Gms)	Sod (Gms)	Cult (Gms)	Sod (Gms)	Cult (Gms)	Sod (Gms)	Cult (Gms)
1	5.78	3.54	2.12	3.63	1.17	4.07	9.07	11.24
3	5.56	8.24	0.53	7.87	0.30	6.38	6.39	22.49
6	1.77	7.62	0.10	9.39	0.21	3.49	2.08	20.50
10	0.66	1.20	0.00	4.25	0.00	0.88	0.66	6.33

*The roots for each sample were from ten 6-inch sampling holes at the depths shown above, but are calculated as the dry weights of roots per 1000 cubic inches of soil. The trees were set out in 1936.

It is of interest to consider the data on lateral distribution of roots. Under sod conditions the greatest concentration of small roots was 1 foot from the trunks, while under cultivated conditions the concentration of small roots was greatest at 3 to 6 feet from the trunks. Rogers and Vyvyan (5) found that small roots fairly uniformly filled the soil both near and far from the trunks of apple trees.

The root systems of trees that had been cultivated 3 years before going into sod (1934 series) were affected in a similar but less severe manner than occurred above on continuous sod. The small roots were reduced in weight over continuously cultivated trees at 6 and 10 feet from the trunks, but not at 1 or 3 feet.

Composition of Leaf Blades as Affected by Sod:—There was very little difference in the N, P, K, Ca, or Mg content of leaf blades between the sod (1936 series) and cultivated trees. These results are not stressed since analyses were not made in previous years when differences might have been apparent. Differences in size of the trees and yields of tung nuts might have influenced the results.

The N and P content on the leaf blades were lower under sod (1934 series, cultivated for 3 years) than on continuously cultivated trees (Table II). In one block of trees where the top soil had washed away the sod very seriously competed with the trees for nitrogen. The unfertilized trees on sod were about dead, while adjacent trees on sod, fertilized with sodium nitrate, were in much better condition. Nearby, unfertilized but cultivated trees were healthy, but not vigorous.

TABLE II—COMPOSITION OF LEAF BLADES FROM TUNG TREES UNDER CULTIVATED AND SOD (1934 SERIES, CULTIVATED 3 YEARS) CONDITIONS (1941)

Material	Cultivated (Per Cent)					Sod (Cultivated 3 Years) (Per Cent)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Leaf blades (May 15)	2.04	0.16	1.31	2.59	0.56	1.88	0.15	1.43	2.87	0.63
Leaf blades (Aug 25).	1.71	0.15	0.88	3.10	0.45	1.16	0.10	0.76	3.28	0.58
Leaf blades (Nov 3) . .	1.34	0.17	0.53	3.15	0.47	1.10	0.13	0.55	3.40	0.51

Soil Aeration Under Sod and Cultivated Trees:—Early in these studies it was thought that a difference in aeration between surface and subsoil might affect the distribution of roots. It was also thought that the poorer root development that occurred under sod might also be a result of poor aeration. Table III gives the results of these studies. Apparently, aeration was very good under both cultivated and sod conditions and at all depths from 8 to 72 inches; aeration could hardly have been a factor influencing the distribution of roots on Ruston sandy loam.

TABLE III—THE PERCENTAGE OF OXYGEN IN THE SOIL AIR AT DIFFERENT DEPTHS UNDER SOD AND CLEAN CULTIVATION ON RUSTON SANDY LOAM*

Depth (Inches)	May 19, 1941		Aug 25, 1941		Nov 7, 1941		Feb 10, 1942		Mar 9, 1942		Jul 14, 1942	
	Sod	Cult	Sod	Cult	Sod	Cult	Sod	Cult	Sod	Cult	Sod	Cult
8	20.5	20.7	20.8	20.7	20.3	20.4	20.8	21.0	20.8	20.9	20.9	20.3
15	20.4	20.5	20.7	20.4	20.3	20.5	20.8	21.0	20.8	20.8	20.3	20.0
30	20.4	20.3	20.3	20.4	20.0	20.7	20.7	20.9	20.8	20.8	20.1	19.8
48	20.3	—	19.8	—	20.0	—	20.7	—	20.3	—	20.1	—
72	—	—	—	—	—	—	20.5	—	20.4	—	19.8	—

*Carbon dioxide varied from a trace to 2.0 per cent; most readings were 0.4 to 0.9 per cent, all results are averages from duplicate wells.

Chemical Composition of the Soil and Root Distribution:—In Table IV is presented an example of the data obtained on the chemical composition of the soil and distribution of roots. The data on chemical

TABLE IV—THE DRY WEIGHTS OF SMALL TUNG ROOTS (0 TO 1 MILLIMETER DIAMETER) AT DIFFERENT DEPTHS AND THE CHEMICAL COMPOSITION OF THE SOIL*

Depth (Inches)	Dry Weight of Roots (0–1 Mm Diameter) per 1000 Cu In Soil	Total N (Per Cent)	Available† P (Per Cent)	Exchangeable Bases (ME Per 100 Gms)			pH
				K	Ca	Mg	
0–2	14.0	—	—	—	—	—	—
2–4	11.9	0.041	0.037	0.12	1.33	0.29	5.70
4–6	8.0	—	—	—	—	—	—
6–8	3.7	—	—	—	—	—	—
8–10	1.2	—	—	—	—	—	—
10–14	1.1	0.033	0.020	0.06	1.11	0.42	5.25
14–22	0.5	—	—	—	—	—	—
22–34	0.5	0.025	0.019	0.08	0.85	0.60	4.95

*Samples taken 6 feet from the trunks of 5 vigorous 8 year old trees.
†Truog's method.

analyses between surface and subsoil are insufficiently different to explain the differences obtained on the distribution of roots.

Biological Test for Nutrient Deficiency in Subsoil:—It was felt that some biological test of soil fertility might indicate better than chemical analyses whether the differences in root distribution between surface and subsoil were or were not of a nutritional nature. Corn was selected because of the small amount of nutrients in the seeds and because its roots had been observed to be not very abundant in Ruston subsoil, the same as tung roots.

Various C. P. chemicals were added to gallon pots of subsoil at approximately the following rates on an acre basis: 100 pounds N, 686 pounds P_2O_5, 455 pounds K_2O, 143 pounds Ca, 100 pounds Mg, and 133 pounds S. The purpose was to add a considerable surplus of all elements. Single elements were omitted, except the ones to be tested, from the different treatments in order to determine whether any of the above elements limited the growth of corn on the subsoil. The treatments were in triplicate.

The data in Table V show that the growth of corn was limited, first, by the lack of nitrogen and second, by the lack of phosphorus. The growth of corn without the addition of nitrogen or phosphorus was only two or three times the original weight of the seeds. The growth of corn on unfertilized top soil was much greater than this. Potassium, also, limited corn growth but not until the corn was about 2 months

TABLE V—EFFECT OF VARIOUS CHEMICALS ON THE GROWTH OF CORN (3 MONTHS) ON RUSTON SANDY LOAM SUBSOIL*

Treatment	Average Dry Weight Per Plant (Roots and Top) (Gms).
Complete (N P K Ca Mg S)	10.0
Minus N (P K Ca Mg S)	1.1
Minus P (N K Ca Mg S)	1.4
Minus K (N P Ca Mg S)	6.0
Minus Ca (N P K Mg S)	10.0
Minus Mg (N P K Ca S)	10.0
Minus S (N P K Ca Mg)	11.0
Nothing added	1.1

*Each result is the average from 3 pots and 3 plants per pot.

old. It would seem that tung root development in the subsoil would be limited by the same factors that limited corn growth — first, lack of nitrogen, and second, lack of phosphorus. Nitrogen and phosphorus would have to be increased to a considerable extent before potassium could be deficient and limit root growth.

SUMMARY

A study was made of some factors affecting the distribution of small tung roots (0 to 1 millimeter in diameter) in Ruston sandy loam. Small tung roots were more concentrated near the surface under sod than under cultivated trees. The effect of sod, also, was to reduce the number of roots in a given volume of soil. Small tung roots had a fairly uniform horizontal distribution up to 6 feet from the trunks and were still abundant 10 feet from the trunks, especially under cultivated trees. Small tung roots were very abundant in the surface black soil but scarce in the tan or reddish subsoil. Abundant root growth occurred in the subsoil only in those places where old forest tree roots had burned or rotted. Most of the large roots were 18 inches deep or deeper, which contrasted with the most intense small root development in the surface 6 inches.

Aeration did not seem to be a factor influencing root distribution, either under sod or cultivated trees. Ruston sandy loam must be classified as a very well aerated soil. The subsoil was very deficient in available nitrogen and phosphorus, as measured by the growth of corn. The lack of available nitrogen and phosphorus probably accounts for the poor tung root growth in the subsoil in comparison to the good growth in the surface soil.

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Mulch Versus Cultivation in the Young Tung Orchard

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MULCHING is no new practice in the field of horticulture. It has been tried on practically all the tree fruits, many of the small fruits, and to a limited extent on vegetable crops. Green and Ballou (7) found the growth and yield of young apple trees greater with mulch culture than with tillage and a cover crop. Langord (10) working with sour cherry, Baker (2) working with peach and apple, and Clark (4), Darrow and Magness (5), and Havis (9), working with raspberries, all cite beneficial results obtained by the use of mulches. Chandler and Mason (3) report that mulch reduces growth of blueberry plants on sandy soils, but increases their growth on clay loam.

Tung orchards in the southern United States are extensive and because of the relatively low value per acre of the crop, costs of operation must be kept at a minimum. Consequently, any mulching materials used would need to be cheap and readily accessible.

With this in mind, an experiment was begun in August, 1940, in a seedling tung orchard near Lloyd, Florida, that had been planted the preceding January. The trees are 20 feet apart in the row, and the rows, which are planted on the contour, are on the average about 35 feet apart. The mulch consisted of weeds and *Crotalaria spectabilis* grown in the middles between the rows. Thirty-five pounds green weight was cut and applied per tree when the experiment was begun in August, 1940; 75 pounds per tree was applied in July, 1941; and 75 pounds again in July, 1942. This material contained about 75 per cent moisture when cut, hence the amount of dry matter used per tree was relatively small. It was placed on a small area immediately adjacent to the tree trunk extending out to about one-half of the spread of the branches. A strip about 6 feet wide on either side of both mulched and unmulched rows was disced, three or four times each season. The principal difference between the treatments is that, in the one case, the area next the trunks of the trees was mulched, and in the other, it was hoed by hand twice each season. All trees were fertilized by the grower, using approximately 2 pounds per tree of a home mixed fertilizer of 4–7–6 composition. In the case of the mulched trees, the fertilizer was applied on top of the mulch.

In November, 1942, it was evident that the mulched trees were larger, and in better condition than those not mulched. Measurements were taken of the height and spread of the trees, the trunk circumference, and the shoot growth in 1941 and 1942. The weight of the fruit was recorded and the condition of the foliage of each tree was rated. The arrangement was systematic, every other row being mulched. Some trees in each treatment were destroyed by a hurricane in October, 1941. More of the mulched trees were broken than the cultivated trees because of the fact that they were more vigorous and succulent at the time of the hurricane. Data were taken from

25 cultivated trees and 21 mulched trees. These are compared as independent or non-paired samples, according to the method described by Goulden (8). The data are given in Table I.

TABLE I—COMPARISON OF MULCHED WITH CULTIVATED TUNG TREES

Treatment	Height, Nov, 1942 (Ft)	Spread, Nov, 1942 (Ft)	Girth of Trunk, Nov, 1942 (Cms)	Shoot Growth, 1941 (Cms)	Shoot Growth, 1942 (Cms)	Yield Per Tree, 1942 . (Pounds)	Leaves Showing K Deficiency,† (Per Cent) Nov 8, 1942	Defoliation (Per Cent) Nov 8, 1942
Mulched	13.6	17.8	30.9	1399	569	10.8	41	1
Cultivated	11.0	14.2	22.4	708	475	4.6	97	34
Difference	2.6	3.6	8.5	691	94	6.2	56	33
t*	5.78	6.40	8.98	4.37	1.86	6.76	9.01	4.71

*t – @.05 = 2.01 t – @.01 = 2.69.

†Percentages based on leaves remaining on trees.

At the time the orchard was planted in January, 1940, uniform seedlings of almost identical caliper were selected from a large nursery for this experiment. The data in Table I show that in November, 1942, the mulched trees were on the average 2.6 feet higher, 3.6 feet wider, and the girth of the trunk at 6 inches above the ground was 8.5 centimeters greater than for the corresponding cultivated trees. All of these differences are supported by very high statistical odds. The amount of shoot growth on each tree was estimated by measuring all of the new growth arising from five terminal buds of the preceding season taken at random. The growth measurements for each tree were summed up and it may be noted that in 1941, the average total per tree was 1399 centimeters for the mulched trees, as against 708 centimeters for the cultivated trees.

In 1942, however, there was no significant difference in the amount of shoot growth between the mulched and the cultivated trees. It is believed that this lack of significant difference is due to the fact that in 1942, the mulched trees carried a much heavier crop of fruit than the cultivated trees. The average production of the mulched trees was 10.8 pounds of fruit, whereas the production of the cultivated trees was only 4.6 pounds, or less than half as much. It has been repeatedly observed in the past with tung that fruit production reduces shoot growth.

In July, 1941, a severe foliage disorder was first observed generally throughout the district in which this orchard is located. This disorder has since been diagnosed by Drosdoff and Painter (6) as due to deficiency of potassium. When this orchard was visited in August, 1941, it was apparent that the symptoms of this disorder were much more prevalent on the cultivated trees than on the mulched trees.

In 1942 it was again evident that mulching had reduced the prevalence of the potash deficiency pattern. Estimates were made of the percentage of leaves on each tree exhibiting the deficiency symptom. Leaves that are severely affected with this disorder have a tendency to drop prematurely; consequently, an estimate was made of the percentage defoliation as of November 8, 1942. No frost having occurred, normal trees still carried all their leaves on this date. Referring to the data in Table I, it may be seen that the cultivated trees had lost 34 per cent of their leaves, and 97 per cent of the remaining leaves showed the potash deficiency pattern. However, the mulched trees had an average of 41 per cent of the leaves affected, and only 1 per cent defoliation.

Mulching may benefit an orchard by improving the physical condition of the soil including its ability to absorb moisture, and by reducing the rate of moisture loss from the surface. Woodbury, Oskamp, and Noyes (12) found the moisture percentage of the soil under a mulch continuously higher through the summer than that of a soil with cultivation and cover crop. Albrecht (1) found mulched uncropped soil too wet for good tilth. The mulch also releases plant nutrients to the trees as it decomposes. Wander and Gourley (11) were first to point out that a straw mulch tends to augment greatly the amount of replaceable potassium in the soil. Baker (2) and Langord (10) have presented similar evidence. In addition, the mulch is certainly of benefit in controlling weeds and grass. All of these factors probably played a role in the experiment reported here, but in view of the known deficiency of potassium, it is likely that the increase in available potassium was of prime importance. Drosdoff and Painter (6) have shown that the samples of leaves taken in August, 1941, from the mulched trees in this experiment contained twice as much potassium as those from corresponding cultivated trees.

The practice of mulching young tung orchards with materials grown between the rows of trees is perfectly practicable. Mr. Herbert Stoddard of Thomasville, Georgia, has used mulches of *Crotalaria intermedia* and hairy vetch in an orchard from the time of planting in February, 1941. This practice in this instance, has produced better trees with less expense than any method previously tried. The evidence warrants an extensive commercial trial of mulching in young tung orchards.

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Some Effects of Cover Crops in Peach Orchards on Runoff and Erosion[1]

By R. B. ALDERFER and NELSON J. SHAULIS, *Soil Conservation Service and Pennsylvania State College, State College, Pa.*

COINCIDENT with the recognition which is given to the use of soil conservation practices in general farming is an increasing appreciation of their value in orchard soil management. Collison and Carleton (3), Browning and Sudds (2), and Li *et al.* (6) are a few of the horticulturists who have recently studied this subject. The research of Duley and Kelly (4) is especially applicable to this problem.

The purpose of this investigation was to measure the effect of various types of cover crops on the conservation of soil and water in peach orchards in south-central Pennsylvania. Use of this method of soil maintenance is controversial because it involves the amount of competition with sods or cover crops to which it is practicable to subject fruit trees. This study was conducted in 1941 and 1942 in commercial peach orchards within a 7-mile radius of the Fruit Research Laboratory of The Pennsylvania State College at Arendtsville, Adams County, Pennsylvania.

At the C. E. Raffensperger orchard the soil is Penn shale loam which is 1½ to 3 feet deep. This soil is compact and susceptible to sheet erosion. At the Oyler, Garretson, and Quigle orchards the soil is Ashe loam which is 4 to 8 feet in depth and less susceptible to sheet erosion than the Penn shale loam. The loose, unconsolidated subsoil of the Ashe loam renders it subject to gully erosion. It is an excellent fruit soil. A description of each study site is contained in Table I.

A type-F rain-simulator, or infiltrometer (5), was used to measure the capacity of the soil at each site to infiltrate, or to detain on its surface, the artificial rainfall applied. It consisted of a 6- by 12-foot plot enclosed by sheet iron borders extending into the soil to a depth of 4 inches. The total area wetted was about 9 by 15 feet. Runoff was intercepted by a concentrator trough at the downstream border of the plot and directed through a small type-H flume where point gage readings of flow depth were taken at recorded intervals during the rainfall and the corresponding runoff period. These point gage readings were transposed to runoff intensity equivalents, represented in per cent runoff, and the data plotted.

For the data on soil loss, runoff samples were obtained during the period of equilibrium runoff for each "rain".

The "rain" produced by the infiltrometer was applied at intensities

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TABLE I—Experimental Areas (Descriptions of Sites of Runoff Trials)

Cover	Date of Run	Descriptive Notes	Per Cent Slope	Per Cent of Soil Covered by Vegetation
C. E. Raffensperger Orchard				
Legume sod rotation	Aug 6, 1941	Plant residues cover 90 per cent of soil surface. Legumes: alfalfa, with red, alsike, and Ladino clovers.	6	80
Korean lespedeza	Aug 6, 1941	Roughly cultivated surface; last cultivation in Nov 1940.	6	60
	June 16, 1942	Surface dispersed, no grass; 50 per cent lespedeza and 50 per cent weeds.	8	65
Clover with alternate row cultivation; clover cover	June 18, 1942	Untilled for 12 months; 35 per cent of soil surface is covered with residue. Many weeds.	8	95
Clover with alternate row cultivation; cultivated	June 17, 1942	Disced 8 weeks prior to run; no plant residue; 15 per cent alfalfa, 50 per cent plantain and weeds, 35 per cent foxtail.	6	85
	Aug 8, 1942	Fitted, seeded June 21 to red, alsike, and Ladino clovers.	6	70
Crimson clover and vetch	Aug 5, 1941	Fitted and seeded July 15; 15 per cent residue on surface.	6	15
	Oct 5, 1942	Fitted and seeded in mid-July; 8 inches of cover. Duplicate areas on this data.	8 and 7	95 and 90
Cultivation	Aug 6, 1941	Fitted and seeded to Sudan grass July 15. No residue on surface.	5	0
	Oct 6, 1942	As above. Mowed Aug 25, 1942; new growth 10 inches high.	6	65
Orchard grass disced and and seeded to Ladino	June 17, 1942	Orchard grass (1938-39). Reseeded in May 1940. Fitted and seeded to Ladino in Apr 1941 and 1942. No plant residue on surface.	10	20
H. F. Quigle Orchard				
Clean cultivation	Aug 7, 1941	No surface residue, very clean cultivation.	5	0
John Garretson Orchard				
Cultivation and weeds	Aug 7, 1941	Heavy, platy, fine stones on soil surface. Major weeds: sorrel and foxtail.	5	40
D. F. Garretson Orchard				
Disced orchard grass	Aug 8, 1941	Very heavy, partially turned under orchard grass. Rough surface for high water detention.	6	85
William Oyler Orchard				
Ladino clover seeding	June 18, 1942	Heavy rye grass sod disced and seeded May 9; 8 inches of rye grass; no Ladino; slaked surface. No plant residue on surface.	9	25
Ladino clover	Oct 8, 1942	Heavy Ladino cover has suppressed all rye grass. No surface residue.	8	100
Rye grass (mature)	June 19, 1942	Very heavy rye grass (18 to 24 inches). Half of soil surface is residue-covered.	8	95
Rye grass (disced)	Oct 18, 1942	As above but disced two ways July 2. Numerous disc depressions. Much of rye grass was incorporated.	9	60

of 1½ and 3 inches per hour. It was possible to produce these two intensities by operating one-half or all of the nozzles at uniform water pressure during any one application. The data reported are from the runs made several hours after or on the day following the initial run of 1½ inches per hour, at which time the soils were rather uniformly wetted.

Approximately 250 gallons of water were applied at each run. No run was less than 30 minutes in duration and some were 60 minutes, or as long as necessary to obtain the equilibrium rate of runoff for at least 20 minutes.

The intensity of 1½ inches per hour is equal to the 10- to 30-minute maximum intensity of many showers and moderate rains, while the 3-inch intensity is the 10- to 15-minute maximum of a heavy storm. Yarnell (8) indicates that a 10-minute rainfall at the rate of 3.8 inches per hour could be expected in this locality once in 2 years. At the Raffensperger orchard a recording rain gage indicated nine rains of intensities of 1.5 to 2.8 inches per hour for periods of 10 to 26 minutes in the interval from May 7 to June 23, 1942.

RESULTS

The runoff hydrograph in Fig. 1 shows four curves representing the rate of runoff from four orchard plots on the Penn shale loam. Similar curves were plotted for every run made. The points A, B, C, and D are taken to characterize the curves, and these data for all the runs are presented in Figs. 2, 3, 4, and 5. The lines connecting the points in Figs. 2, 3, and 4 are only to connect like points.

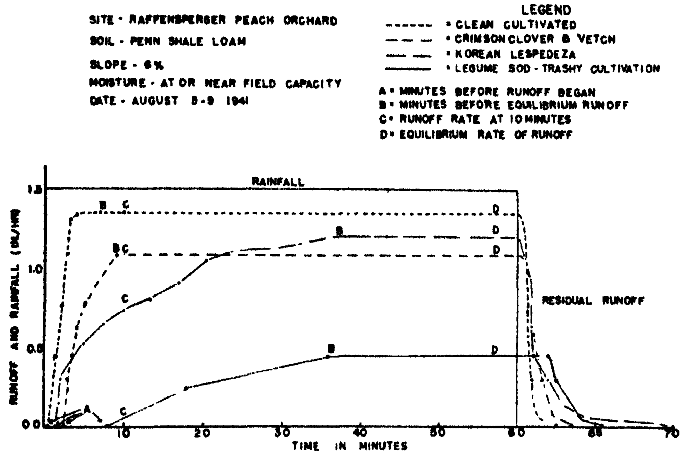

FIG. 1. Runoff Hydrograph of four orchard cultural plots.

DISCUSSION

Studies on Penn Shale Loam:—Five different treatments were investigated with regard to their effectiveness in controlling the loss of water and soil from a peach orchard on Penn shale loam. Measurements were made in August 1941 and in June and October 1942. Fig. 2 presents the August 1941 and October 1942 data. Only those two plots which produced the greatest runoff in August 1941 were re-examined in October 1942. Each of the orchard soil treatments will be mentioned in the order in which it appears upon analysis of

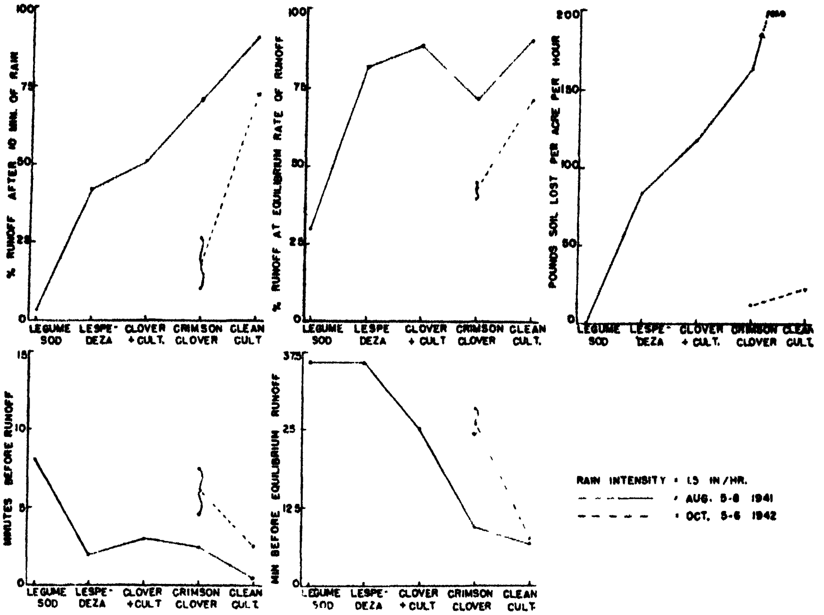

FIG. 2. Runoff and erosion from orchard soil management plots on Penn shale loam.

the runoff data (Figs. 1 and 2) to have been effective in the detention and infiltration of rainfall during the August 1941 "rain".

The legume sod (alfalfa and clover) was the best of the five treatments. It was trashily[2] disced in April, May, and June; but there still remained in August, when its capacity to retard runoff and erosion was measured, a highly effective cover of legumes and weeds growing up through the trash.

The lespedeza cover at this date had effected water retention second only to the legume sod. In June and November 1940 this cover was trashily disced. There was no tillage in 1941 until November; hence, the August "rain" fell on a cover that remained effective for the early portion of the run.

The clover cover crop with trashy cultivation in alternate rows was in the group of covers showing a control of runoff intermediate between clean cultivation and legume sod. In successive years any one area has clover sod, trashy cultivation, and clover sod. In August 1941 the seeding of June 1941 accounted for only 10 per cent of the cover; there was a large amount of weeds in the cultivated portion of this plot. In the adjacent row, the clover or sod half which was not tested, it would be expected that the June 1940 seeding that had more legumes would be just as effective as the cultivated portion.

The crimson clover and vetch plot had a heavy growth of vegetation up to mid-June, when it was lightly disced. In mid-July the plot was trashily fitted and reseeded. Thus, in early August the plot had a minimum of surface cover. Soil and water losses were severe when "rain" was applied to this unprotected surface. As in the clover cover crop with alternate-row cultivation, we are dealing with a cultural system that has periods of excellent soil protection and periods of high susceptibility to runoff and erosion when unprotected due to clean cultivation or seeding. The striking feature of the data herein obtained is the low residual effect of the incorporated cover on soil permeability and resistance to erosion.

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[2] Trashy cultivation is an incomplete discing or harrowing which permits much of the plant material to remain on the surface.

The clean cultivated orchard treatment was the least effective from the standpoint of soil and water conservation. This plot was clean cultivated four times during the spring and early summer and was then seeded to Sudan grass in mid-July 1941. This plot had less ground cover immediately prior to the run than at the time the "rain" was applied, at which time Sudan grass seedlings were noticeable. All the covers seeded in the summer of 1941 were slow or failed to become established because of intense drought.

In order to determine the effect of the Sudan grass on the clean cultivated plot and the crimson clover and vetch after they had become established following their mid-July seeding, rain at erosive intensities was applied again in October. The runoff data obtained are presented in Fig. 2. The superiority of the crimson clover and vetch as compared with the Sudan grass is consistent with that shown by the data of August 1941. Its greater superiority as reflected in the October performance is probably due to the ground cover, which was very much heavier than in August. In order to determine the effectiveness of this heavy crimson clover cover in runoff control, all of the vegetation growing within the runoff plot area was clipped and removed, allowing only a short stubble to remain on the surface. "Rain" at the 1½-inch intensity was applied again. The percentage of the rainfall lost as runoff was increased from 42 to 72. Sudan grass does not cover the ground so rapidly as does crimson clover.

Runoff measurements were repeated upon some of the cover crop treatments in June 1942, using intensities of 1½ and 3 inches per hour, and the data are presented in Fig. 3. Analysis of the data shows that there was more runoff from the lespedeza plot than from the cultivated portion of the plot with clover and alternate-row cultivation. This order is the reverse of that in August 1941, but the order fits the conclusion obtained then. The lespedeza plot was trashily disced in November 1941 and, with the dependence on self-seeding of a low-volume cover, the amount of soil covered was not very high in June and runoff was high. In the cultivated portion of the clover plot with alternate rows cultivated, the runoff was less because the spring discing had left a rather rough surface for depression storage, and the weeds and volunteer cover offered more soil protection than did the lespedeza. If the superiority of the cultivated portion over the sod portion of this clover plot with alternate rows cultivated is significant it can be traced only to the greater amount of depression storage in the cultivated portions and the greater rapidity with which broad-leaved weeds such as plantain cover the ground.

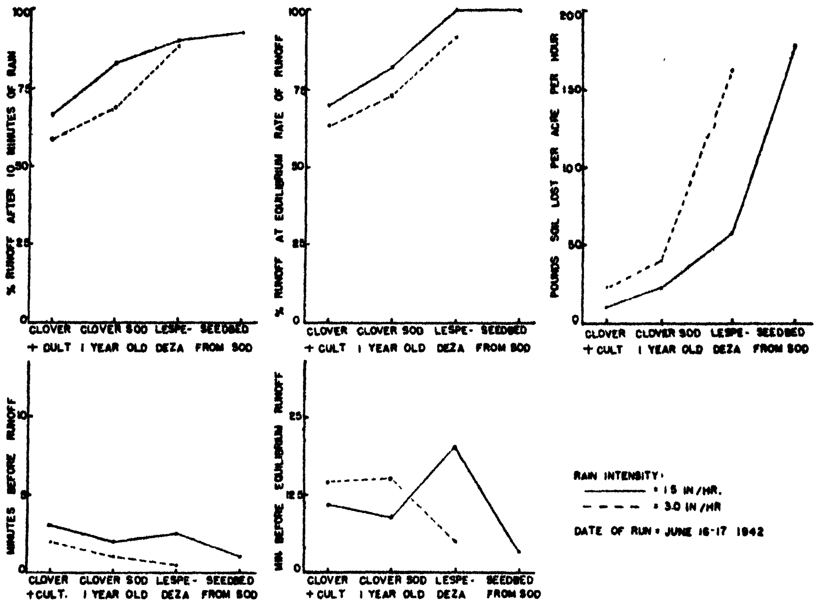
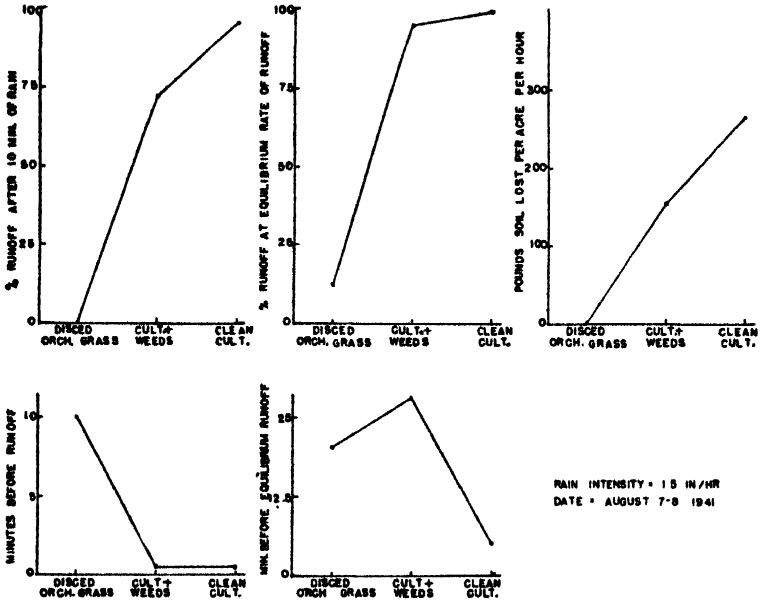


FIG. 3. Runoff and erosion from orchard soil management plots on Penn shale loam.

The "seedbed from sod" was an area fitted and seeded 6 weeks prior to the "rain". It had been in orchard grass sod for 2 years and then disced once in 1940, 1941, and 1942. This area, as well as the lespedeza plot, had had much of its topsoil eroded and cover establishment was difficult. In this case the readily slaked subsurface of the orchard grass sod was exposed to the rainfall by inverting and a perfect seal to 1½ inches of rain per hour was effected in 8 minutes. The water-stable aggregation developed in the orchard grass area was not effective after thorough seedbed preparation.

Studies on Ashe Loam:—In August 1941, runoff and erosion measurements were made on three peach orchards, of which one had clean cultivation, one had cultivation with sparse weeds, and one had partially disced orchard grass. This soil is not a dense one; peach rooting penetrates at least 8 feet (7). The subsoil is unconsolidated and easily gullied.

Runoff data illustrating the effectiveness of these three treatments on the Ashe soil are presented in Fig. 4. The water loss under clean cultivation amounted to more than 95 per cent in less than 10 minutes. With sorrel, cinquefoil, and foxtail covering 40 per cent of the soil in an orchard which received two to three cultivations prior to mid-July, there was a reduction in runoff as compared with clean cultivation. The soil loss was reduced 40 per cent. Not more than 80 feet from this site an adjacent peach orchard had a 2-year-old orchard grass sod which was trashily cultivated one to three times each summer. Here



RAIN INTENSITY = 1.5 IN/HR
DATE = AUGUST 7-8 1941

FIG. 4. Runoff and erosion from peach orchards on Ashe loam.

there was no runoff after 10 minutes of a 1½-inch "rain" and only 13 per cent after 28 minutes. No soil loss occurred. The presence of the orchard grass has had a moderately depressing effect on peach growth in drought periods; this effect was only slight with higher rainfall. Orchard grass was used as a cover because the owner desired to prevent further gullying of this orchard.

These data are probably representative of the water conservation under these covers through most of the growing season. They emphasize the very high water loss which is incident to clean culture under rains of moderate intensity (1½ inches per hour). It is a fact that the period of greatest cultivation, May, June, and July, occurs with the period of most intense rainfall, June, July, and August (1).

At the William Oyler peach orchard on Ashe loam, data were obtained in a study of the change in infiltration capacity incident to seedbed preparation and cover crop growth. This was abandoned land in 1939. In 1940 a peach planting was made with strip cultivation along the tree rows. In 1941 and to May of 1942 the entire orchard was in domestic rye grass. On May 9, 1942, one portion of the orchard was fitted and seeded to Ladino clover. When the first series of runs was made in late June 1942, the Ladino was scarcely effective as a ground cover, but volunteer rye grass covered 24 per cent of the soil surface. The undisturbed rye grass was 2 to 3 feet high and covered 95 per cent of the soil surface.

Four weeks after the June 1942 run, the previously undisturbed rye grass was disced thoroughly in two directions. There was a natural reseeding, and in 10 weeks (early October) the runoff study was

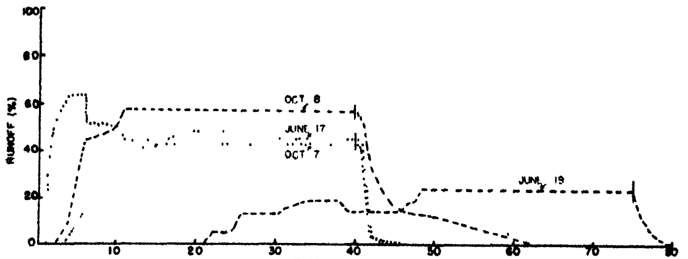


FIG 5A RAIN APPLIED AT 3.0 INCHES PER HOUR

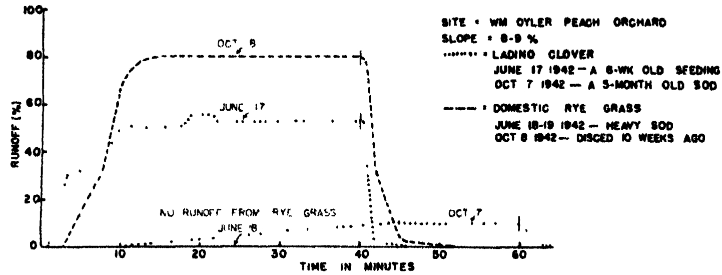


FIG. 5B RAIN APPLIED AT 1.5 INCHES PER HOUR

FIG. 5. Runoff Hydrograph of two orchard cultural plots.

repeated. During this period the Ladino clover had covered the ground completely and suppressed all the rye grass.

The runoff data are included in Fig. 5 for each of the two cover types at the June and October measurement periods. In June there was no runoff or soil loss from the undisturbed rye grass when subjected to 1½ inches of "rain" per hour; 24 per cent of the rainfall but no soil was lost at the 3-inch intensity. When the mature rye grass tops were clipped and removed and "rain" was again applied no runoff occurred during the 1½-inch intensity, but runoff was increased to 50 per cent under a 3-inch intensity. This is in contrast to the 6-weeks-old seedbed for Ladino clover, from which about 50 per cent of the rainfall was lost at each intensity level, with a corresponding soil loss of 63 and 100 pounds per acre per hour, respectively, for the two intensities.

The high degree of protection from runoff was maintained in the rye grass until the mid-July cultivation. It is believed that the effectiveness of this cover was at a minimum after the first high intensity rain which followed the cultivation and that at the October runs its effectiveness was increasing. But, 10 weeks after the cultivation, the runoff was as high as that from the Ladino seedbed tested in late June. There was, however, only a slight increase in erosion on the disced rye grass plot.

Conversely, the Ladino clover plot increased in effectiveness of runoff control so that in October it completely retained the 1½-inch per hour "rain" for 10 minutes. Erosion was completely controlled. At the 3-inch per hour intensity there was as much runoff after 12 minutes as during the June trials.

SUMMARY AND CONCLUSIONS

These data emphasize the relatively abrupt decrease in infiltration capacity effected by the incorporation with the soil of a heavy cover crop and the relatively slow development (several months) of the soil-plant relationship which effects a high infiltration capacity. Removal of the cover crop from the soil surface by incorporation with the soil or by mowing and removal of the mowings will increase runoff.

The objection has not been overlooked that the soil management, aside from mulching, which is best for reducing runoff and erosion is not the best for the production of peaches, sour cherries, or grapes. The solution seems to be in the restriction of fruit plantings to soils which are sufficiently deep to permit the growth of heavy cover crops, and trashy cultivation of these soils to permit a large amount of the plant material to remain on the surface. The frequency of seedbed preparation should be reduced.

On the basis of these observations, the actual ground coverage by growing or dead plant material and the amount of depressions for water detention are the two factors most important in controlling runoff. The amount of material which had grown on the soil, but which at the time of the trial was removed or incorporated, had a relatively minor role in runoff control.

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Hay Mulches in Apple Orchards[1]

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ORCHARD mulching experiments have been carried on at the Massachusetts Experiment Station for the past twenty years. The first comparison was of mulching and cultivation with McIntosh and Wealthy trees. Mulch was first applied in rather large amounts in 1922 when the trees were 10 years old. In later years, more material was applied at somewhat irregular intervals when material was available. The cultivated plots were without fertilizer until 1931 when about 300 pounds per acre of nitrate of soda were used annually. Later, in 1938, potash was added to the nitrogen. The applications of nitrogen and potash were made because the trees appeared to be tending toward a decline. They seemed to respond to the fertilizer. The McIntosh orchard was ruined by the hurricane of 1938, but the Wealthy trees still continue. No mulch has been added since 1939, yet a layer of 8 to 10 inches still remains with grass growing up through it. The trees are still vigorous and maintain their superior production over the plot in cultivation with fertilizers. No fertilizer, other than that in the hay mulch, has been applied to the mulched plots at any time. Results from this orchard were reported in Massachusetts Experiment Station Bulletin 328.

The average annual tree yields in pounds to 1942 are shown in Table I (Blocks G and H). They are computed by two-year periods, but the averages given are for annual yields. The mulched trees produced more heavily and the differences are highly significant as shown by the "t" values 4.055 and 8.679. The mulched plots, at least for the McIntosh, may have been on a better soil, but it is believed that most of the differences in yield are due to treatment.

TABLE I—YIELDS OF MULCHED AND NON-MULCHED APPLE ORCHARDS

Block and Variety	Year	Average Annual Yields (Pounds Per Tree)		"t" Values	Degrees of Freedom
		Cultivation	*Mulch*		
Block G—McIntosh . .	1923-38	298	454	4.055†	7
Block H—Wealthy . .	1923-42	298	417	8.679†	9
		Sod	*Mulch*		
Block E—McIntosh	1937-38	267	296	0.432	9
	1939-40	735	698	0.647	9
	1941-42	754	1,122	4.699†	9
Block D—McIntosh . . . South Plot	1939	461	483	0.452	7
	1940	206	143	1.881	7
	1941	258	333	0 268	7
	1942	817	1,091	3.332*	7
Block D—McIntosh. . . . . North Plot	1939	290	226	2.376	5
	1940	105	110	0.747	5
	1941	171	229	0.729	5
	1942	609	930	2.972*	5

*Significant at the 5 per cent level.
†Highly significant.

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[1] Contribution No. 466 of the Massachusetts Agricultural Experiment Station.

A second mulching test was started in 1938 with a block of 10 McIntosh trees then 26 years old which had been in cultivation with no fertilizer for 18 years or more. Under cultivation the trees grew and produced poorly as compared with fertilized plots in the same orchard. In the orchard mentioned above, the first mulch was applied on a trashy growth of grass and weeds, while in this orchard it was applied in midsummer to the bare soil. Results, as indicated by the appearance of the trees, appeared the second year instead of the third year as in the former orchard. In fact, the improvement of the trees in leaf color, growth, and production in the following years was nothing short of astonishing.

These two rows of five trees each are compared with similar adjacent rows growing in sod, one on each side of the mulched plot. Previous to 1938 both of these plots were fertilized with nitrate of soda. Beginning in 1938 the trees on one side have been fertilized annually with moderate amounts of nitrate of soda and muriate of potash, and those on the other side, with the same plus superphosphate. Incidentally, these two plots of 10 trees each show a larger yield with the nitrogen-potash treatment. It is possible that the phosphorus has favored a more flourishing growth of grass and, with only a moderate amount of nitrogen (300 pounds of nitrate of soda per acre), the grass has robbed the trees of nitrogen. This suggests that with reduced nitrogen, phosphorus may be harmful in sod orchards.

The yields of these trees from 1937 are shown in Table I (Block E). They are given in average annual yield in pounds per tree by two-year periods. The yields on the mulched plot were increased first in 1940. The yield in 1939 was low. For the first two periods, differences are not significant, but those of the 1941–42 period are highly significant ($t = 4.699$). The yield was about 50 per cent more from the mulched trees than from those in the fertilized sod plots.

A third mulching test was started in a 12-year-old McIntosh orchard in 1940. Two plots of eight trees each were mulched with poor hay applied on the bare soil. The rest of the orchard is in ladino clover and has had a nitrogen-potash fertilizer with additional nitrogen under the trees where there is little clover. No fertilizer has been applied to the mulched plots. Here again the mulched trees improved in appearance the second year. The average annual yields in pounds per tree are shown in Table I (Block D). As in the second orchard, comparison is made with the adjacent rows, which are in ladino clover sod. The trees are on clonal stocks, but the comparisons are made of trees on the same stocks. The differences for three years are not significant, but the "t" values for 1942 yields (3.332 and 2.972) are significant at the 5 per cent level. It seems that the hay mulch with no added fertilizer has supplied more favorable conditions for heavy production than the fertilized ladino clover sod.

DISCUSSION

The improvement in appearance and production of orchard trees on our soils where a mulch of poor hay is applied is remarkable. When the mulch is applied to bare soil, these results appear more promptly than when it is applied on a trashy stubble. If one examines the surface soil beneath the mulch a year or two after it has been applied, one finds numerous feeding rootlets. The hay has undergone partial decay and humus is abundant in the lower layer of the mulch and upper layer of the soil.

This condition suggests some reasons for the favorable response of the tree to mulching. (a) The soil temperature is less variable under a mulch than in a soil in cultivation or in sod. This is probably of minor importance. (b) The water content of the soil is higher and more constant than in a cultivated soil or sod. Losses from run-off and evaporation are less. This is more important, especially on certain soils. (c) The surface of the soil under the mulch is loose and well aerated. It has long been known that a well-aerated soil is more favorable for root growth and activity, and this has in recent years been emphasized in its relation to tree fruits.

(d) Probably the most important influence of mulch seems to be a more liberal supply of nutrients for the trees. The hay decays rather quickly and a liberal supply of nitrogen is available to the trees. No signs of a nitrogen depression following mulching have been observed. All these mulched plots are known or believed to have been very low in some nutrients when the mulch was applied. We have found on our soils that with a liberal fertilization with nitrogen, especially with nitrate of soda, a potash deficiency may appear. It may take 10 years or more, but sooner or later it becomes evident. If this potash deficiency is remedied, a magnesium shortage appears on many soils. We seem to be coming to an end of the practice of fertilizing our Massachusetts orchards with nitrogen alone, especially on shallow, eroded soils. A liberal hay mulch supplies all these nutrients and also others, lack of which has not yet been shown. Moreover, the presence of feeding rootlets in the surface layers of the soil suggests that the trees may get these nutrients before they are fixed in a nonexchangeable form in the soil.

Preharvest drop of McIntosh has been heavier on the mulched plots than on those under other systems of management. Yet, in general, more apples have been picked from the trees. Color is often not very good. The appearance of the mulched trees suggests that they may be now in a state of rather high nitrogen nutrition. Perhaps the amounts of mulch applied have been too great for best results. We have used about 4 to 8 tons of air-dried hay per acre per year. Tests are being made of reduced amounts applied only every second or third year.

The practice of mulching orchards with hay, usually that with little value for stock feeding, has given excellent results not only in our experimental orchards, but in those of fruit growers throughout the state. There are many practical considerations involved which are not discussed here. It is not recommended as the one and only best method of orchard soil management, but it is more generally successful than any other single practice.

The Relationship of Compact Subsoil to Root Distribution of Peach Trees

By Herman Hinrichs and Frank B. Cross, *A. and M. College, Stillwater, Okla.*

THIS is a report of the type of root development and top growth made by trees growing in a loose topsoil underlaid by a compact subsoil. During periods of excessive rainfall, peach and plum trees were blown over because of a shallow root system. During dry periods, trees made short top growth resulting in low yields and fruit of poor quality and size.

The survey of literature indicated that root development and production were affected by the porosity and aeration (8) of the soil. Soils having a uniform color in the profile of dark brown at the surface to a lighter brown in the subsoil and containing no mottling of gray (7) were the best.

The root development extends only through the zone of weathering (4) and in a good deep soil (6), the root development of peach trees will be very extensive both laterally and vertically. Dynamiting, digging large holes, and other deep cultural practices to improve soil for tree growing has given variable results. Many investigators (2, 3, 5, 9, 10) have failed to find a sufficient increase in growth or production to be significant and of practical value. Digging large holes has shown to be the most practical method in increasing growth and production of undesirable soils.

MATERIALS AND METHODS

One-year-old Fair Beauty peach trees 5 to 6 feet in height were selected for uniformity and planted February 18, 1939. A second variety, 1-year-old Sun Glo 4 to 5 feet in height were planted April 15, 1939. These trees were planted into a soil containing approximately 12 inches of loose sandy topsoil overlaid by 24 inches of compact subsoil.

Trees were planted under three treatments as to modification of the subsoil. The treatments consisted of (a) digging large holes 5 feet by 5 feet by 4 feet and filling in with top soil; (b) blasting the compressed area with sticks of 60 per cent dynamite set at a depth of 3.5 feet; and (c) planting trees in the smallest hole which would accommodate the roots without bending. The trees were spaced 25 feet by 25 feet and divided into blocks; the Fair Beauty trees in blocks of 12 with four trees to each treatment, and the Sun Glo trees in blocks of 15 with five trees to each treatment.

After one and two years of growth, one average tree from each treatment, with roots attached, was removed for the purpose of making a root distribution study; this was accomplished in the following manner: A deep trench was made just beyond the outer extremities of the tree roots. Working toward the tree, soil was carefully removed until large quantities of roots were encountered. The remainder of the soil was removed by washing with water. A 300-gallon power sprayer operating at 300 pounds pressure was used in the washing process.

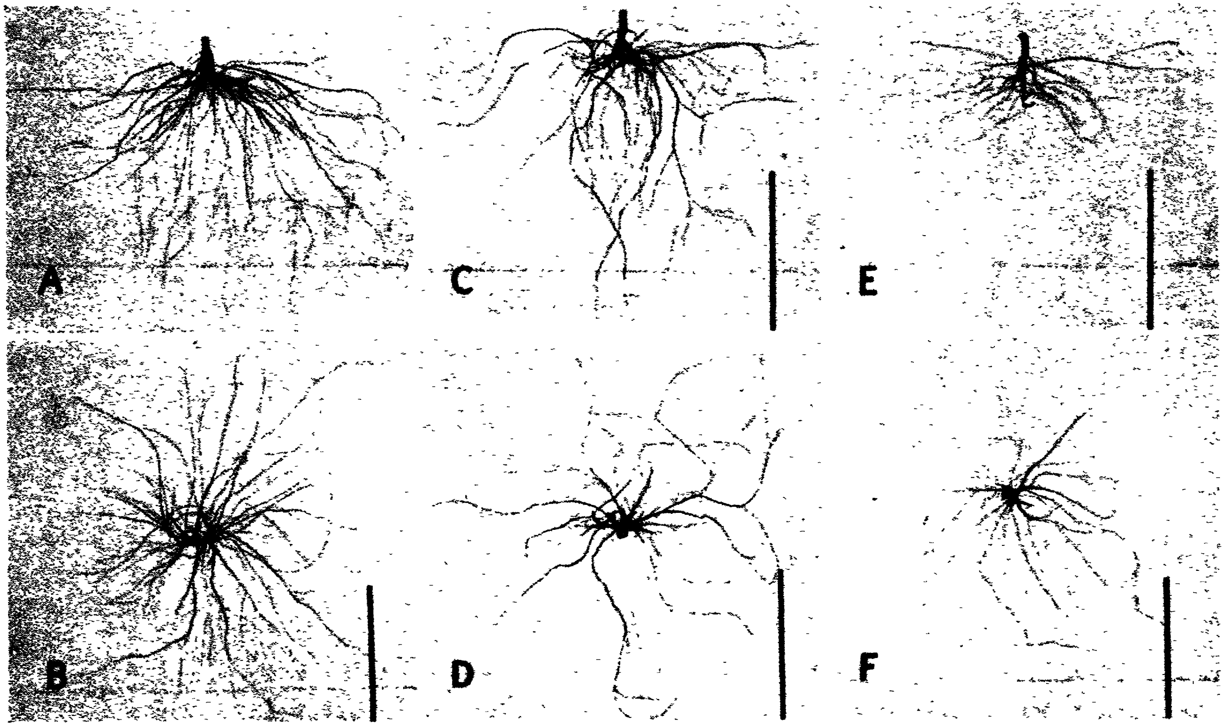

Fig. 1. Root development of Fair Beauty peach trees after one year's growth following tree planting. A and B, dug hole 5 by 5 by 4 feet deep, filled with topsoil; C and D, dynamited hole; E and F, ordinary hole. In each pair of pictures the upper is a side view, the lower is from above looking down. Each picture covers an area about 6½ feet square.

After removal, the roots were photographed and weighed. Fig. 1 shows the type of root systems found, and Table I gives a comparison of the root and top growth from one average tree for each treatment.

TABLE I—ROOT AND TOP GROWTH OF ONE AND TWO YEAR OLD FAIR BEAUTY PEACH TREES UNDER DIFFERENT METHODS OF SUBSOIL TREATMENT

Treatment of Subsoil	Roots			Tops			
	Maximum Spread	Maximum Depth	Total Weight (Lbs)	Maximum Height	Maximum Spread	Total Weight (Lbs)	Number of Blossoms
			One Year Growth				
Ordinary planting	6 ft. 0 in.	2 ft. 0 in.	1.0	4 ft. 5 in.	2 ft. 6 in.	1.3	65
Dynamite	8 ft. 4 in.	5 ft. 0 in.	1.6	6 ft. 0 in.	3 ft. 9 in.	2.4	42
Large holes	12 ft 0 in.	7 ft. 6 in.	2.3	6 ft. 5 in.	4 ft. 6 in.	5.6	309
			Two Years Growth				
Ordinary planting	16 ft 6 in.	4 ft. 0 in.	4.31	7 ft. 0 in.	4 ft. 6 in.	7.95	—
Dynamite	18 ft. 0 in.	5 ft. 9 in.	8.50	7 ft. 0 in.	6 ft. 0 in.	12.00	—
Large holes.	22 ft. 0 in.	10 ft. 0 in.	10.60	9 ft. 6 in.	8 ft. 0 in.	23.32	—

Shoot and trunk growth was measured and recorded for all trees for each block. Measurements in inches of trunk diameters were made 10 inches above the soil line. Three blocks or 36 trees of the Fair Beauty and three blocks of 45 trees of the Sun Glo were measured. The average for each treatment is shown in Table II.

TABLE II—AVERAGE TRUNK MEASUREMENT (INCHES) OF ONE AND TWO YEAR OLD TREES

Treatment	Fair Beauty			Sun Glo		
	1 Year*	2 Years†	Total‡	1 Year§	2 Years‖	Total**
Large holes	0.84	1.09	1.93	0.60	1.18	1.78
Dynamite	0.52	1.08	1.60	0.42	1.09	1.51
Ordinary planting.	0.38	1.04	1.12	0.28	1.01	1.29

*Treatment very highly significant; F value 81.073 exceeds the 1 per cent level of 5.45.

†Treatment not significant.

‡Treatment highly significant; F value 20.28 exceeds the 1 per cent level of 5.45.

§Treatment highly significant; F value 25.14 exceeds the 1 per cent level of 5.25. Location showed to be significant on 5 per cent level.

‖Treatment significant; F value 3.63 exceeds the 5 per cent level of 3.36.

**Treatment highly significant; F value 13.17 exceeds the 1 per cent level 5.25. Location showed to be significant on 1 per cent level.

Moisture, porosity and aeration factors were determined. Soil samples from the area occupied by the roots of fifteen trees were taken on September 30, 1939 and 24 trees on April 20, 1930, for moisture determinations at different levels. A soil tube was used to secure the samples of soil 2 feet from the trunk of the tree. In September, 1940, a portable A. C. Bridge, as described by Bouyocous and Mick (1) was set up to determine the moisture in situ. Tables III and IV indicate the amount of moisture present in soil by sampling of each treatment. Table V gives the pore and air space of the orchard soil at field moisture capacity. Duplicate cores of undistributed soil were taken

TABLE III—THE MEAN PER CENT OF MOISTURE FOR EACH DEPTH UNDER THREE TREATMENTS (SEPTEMBER 30, 1939)

Depth (Inches)	Treatment			Difference Needed to be Significant
	Large Hole	Dynamite	Ordinary	
0 to 12	5.12	5.05	3.83	Not significant
13 to 24*	6.10	9.81	8.40	0.61
25 to 36†	5.85	10.03	9.40	0.846
37 to 48	7.85	8.05	7.80	Not significant
Total	24.92	32.94	29.43	
Average‡	6.23	8.23	7.36	

*Treatment highly significant; F value 24.79 exceeds the 1 per cent level of 8.65.
†Treatment highly significant; F value 18.78 exceeds the 1 per cent level of 8.65.
‡Treatment highly significant.

TABLE IV—THE MEAN PER CENT OF MOISTURE FOR EACH DEPTH UNDER EACH TREATMENT (APRIL 20, 1940)

Depth (Inches)	Treatments			Difference Needed to be Significant
	Large Holes	Dynamite	Ordinary	
0 to 12	13.64	14.74	13.60	
13 to 24*	14.54	17.11	16.74	0.554
25 to 36	15.79	14.89	15.29	
37 to 48†	14.94	12.03	11.97	0.339
Total	58.91	58.77	57.60	
Average‡	14.73	14.69	14.40	

*Treatment highly significant; F value 15.94 surpassed the 1 per cent level of 6.11.
†Treatment highly significant; F value 15.26 surpassed the 1 per cent level of 6.11.
‡Average treatment no significance.

TABLE V—PORE SPACE AND AIR SPACE OF SOIL AT DIFFERENT LEVELS

	Depth (Inches)					
	6	12	18*	24*	36	48
Per cent pore space	42.15	39.72	34.99	33.45	33.88	42.15
Per cent moisture	14.96	15.83	16.49	16.47	13.05	10.34
Per cent air space under above moisture	21.06	16.34	9.22	7.23	11.60	27.15

*The pore space and air space too low under field moisture capacity for proper root development.

from different levels at two locations. The pore space was determined from the real and apparent specific gravity and the air space from the pore space with a known amount of water present.

RESULTS

The modification of the subsoil had a marked influence upon root development and top growth of the trees during the first and second years after planting. Trees in large dug holes developed the greatest root system, extending outward 6 feet and downward to a depth of 7.5 feet in the first year. The root system was more branched and much more extensive than found in other treatments. The root system of trees set in dynamited holes was not so large and well branched as those growing upon trees set in large holes, but they were better than the root systems of trees planted in small holes. The maximum root spread and depth as a result of planting in dynamited holes were

8 feet 4 inches and 5 feet. Root penetration laterally and vertically extended beyond the area visibly affected by dynamiting.

The root systems of trees planted in holes of usual size were very shallow and found mostly above the hard pan. They had penetrated to a depth of 2 feet and spread laterally 6 feet. They were small, very sparsely branched, and had very few fibrous roots as compared to those of large hole plantings. This indicated that a compressed subsoil definitely restricts the development of roots.

The second year proportionate root development was the greatest in the large hole treatment. Trunk and shoot growth of all treatments were directly in proportion to results found in root development. The largest trees came from large hole plantings. Trunk diameter for one year of growth was two and two-tenths times greater for trees planted in large holes than for those in small holes with the subsoil undisturbed.

The analysis of variance on moisture of sampling September 30, 1939 showed that soil in the large hole treatments had a more uniform moisture content throughout the profile to the fourth foot level than the others; also had less total moisture. The large root system which was well distributed through the area evidently removed the available moisture. That the hard pan caused a restriction in movement of moisture and root development was indicated by the higher percentage of moisture therein present. By April 20, 1940, moisture had accumulated and approached field capacity in all treatments which at that time showed about the same total amount of moisture. Again in the large holes a more even distribution of moisture throughout the profile was found. The dynamited soils, however, still indicated the restriction of moisture movement by a higher moisture content at the third foot level. The fourth foot of both the dynamited and undisturbed subsoil was the driest. The Portable A. C. Bridge indicated that moisture percolated very rapidly in large holes and when equilibrium was reached after a rain the moisture was evenly distributed through the profile. During summer months when large quantities of moisture are used, the soil in the large holes becomes the driest, probably because the larger tops and roots are capable of using more moisture.

The pore space between 18- and 36-inch level was too low for good root development. This area was found to have 33 per cent pore space. The soil in the large holes had a higher percentage of pore space. Above 42 per cent was found which indicated the additional air space and available moisture was better for root development. When the moisture in the soil had reached field capacity with the pore space low, the air space would be too low for proper growth and development. Then as the air space came in the range to bring about good growth, the moisture content would be too low. Seven to 10 per cent air space was found in the 18- to 36-inch level under field moisture capacity.

SUMMARY AND CONCLUSION

The data indicate that all treatments to loosen the subsoil were beneficial in increased root extent and distribution and large holes were the most favorable for root development during the first two years.

The root systems as a result of digging large holes were larger and more fibrous, penetrated farther and deeper and made a better anchorage for the tree.

Dynamiting to loosen the subsoil resulted in an increase in root development and top growth, but not extensive enough to make it of practical value.

Moisture content of the soil was more equally distributed throughout the profile in large holes and with roots penetrating to the lower levels the extraction of moisture from all horizons was at a uniform rate.

The pore space measurements indicated the soil from 18 to 36 inches below the surface was too compact to produce a well developed root system. The pore space should be above 40 per cent, but was found to be 33 per cent.

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Solid, Liquid, Gaseous Phase Relationships of Soils on Which Avocado Trees Have Declined

By MARTIN R. HUBERTY and ARTHUR F. PILLSBURY, *University of California, Los Angeles, Calif.*

IN the main, the commercial avocado industry of California has developed during the last 25 years in the mild temperature of the coastal region of Southern California. In seeking favorable climatic

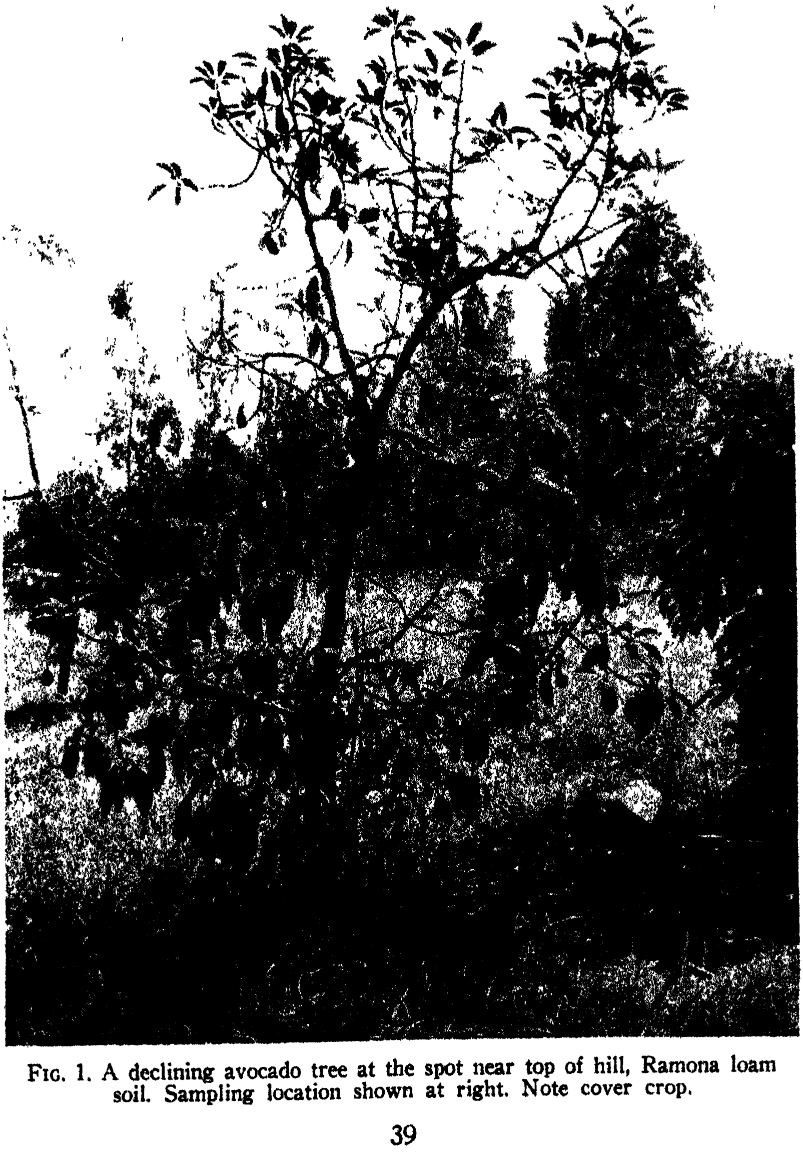

FIG. 1. A declining avocado tree at the spot near top of hill, Ramona loam soil. Sampling location shown at right. Note cover crop.

conditions the developers of avocado orchards have often overlooked undesirable soil conditions, for unfortunately many of the soils in which avocado trees were planted are shallow, heavy textured, and poorly drained. As most of the area planted to avocados had not previously been under irrigation, these undesirable features had not been particularly noted.

It is a common belief, and field observations made by us during 1936–37 indicate that the avocado tree decline disease is normally associated with poor drainage conditions (3, 4). The data herein presented express the solid, liquid, gaseous phase relationships, together with rates of water movement through the various soil horizons of four soil types.

Fig. 1 represents an avocado tree in decline. This disease has been described by Horne (3) and Wager (9) as indicated by a lack of tree vigor, loss of leaves, and a dying back of branches and roots.

In Fig. 2 are shown profile monoliths of soil types on which there has been a considerable amount of tree decline. The profiles from left to right are Altamont clay loam, Fallbrook sandy loam, Las Flores loamy sand, Merriam sandy loam, and Ramona loam. The first two are primary (residual) soils, often occupying rather steep slopes. Las Flores is a marine terrace soil with a loamy sand textured surface and a dense clay pan subsoil overlying a consolidated substratum. At one time avocado trees were planted on this soil type, but it is no longer considered a suitable orchard soil. The Merriam soil is a light reddish-brown soil derived from igneous rock high in quartz. The subsoil is very dense, and calcareous. The Ramona soil differs from the Merriam in that the subsoil is slightly less compact, and the reaction is neutral both in the surface and subsoil.

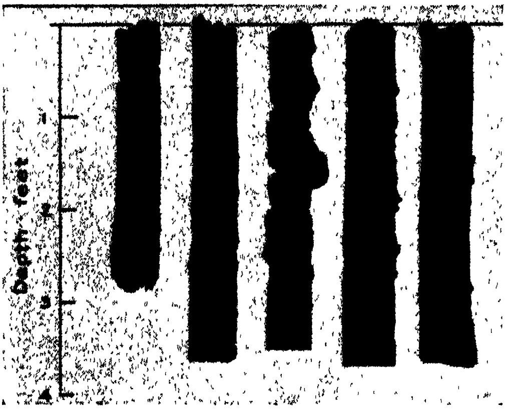

Fig. 2. Profile monoliths of several soils on which avocados have been planted. L to R: Altamont clay loam, Fallbrook fine sandy loam, Las Flores loamy sand, Merriam sandy loam, and Ramona loam.

Characteristics of the last four soils are indicated in Table I. The apparent density of the subsoils (B. horizon) is high in all soil types. This is an important factor in the passage of water through the soils. Field and laboratory permeability measurement on four soil types are reported in Table II. Differences in permeability of the surface and subsoils of the Fallbrook series, while not especially wide, were more pronounced in the in situ field tests than on undisturbed laboratory samples 2 inches in diameter and about 1½ inches in thickness.

TABLE I—SOIL CHARACTERISTICS

Soil and Location	Texture of Sample	Horizon	Depth Sample (Inches)	Real Density $\left(\frac{Gms}{Cm3}\right)$	Apparent $\left(\frac{Gms}{Cm3}\right)$ Density of		Moisture Equivalent	Soil-Water pH (1:2 Suspension)	Mechanical Analysis					
									Wet Sieve Method (Per Cent)		Hydrometer Method (Per Cent)			
					Moist Soil	Air-Dry Clods			<2.362 (Mm)	<1.651 (Mm)	<1.168 (Mm)	<0.05 (Mm)	<0.005 (Mm)	<0.002 (Mm)
Fallbrook...... (Ridge)	Fine sandy loam	A	1	—	1.16	—	—	—	—	—	—	—	—	—
	Fine sandy loam	A	2	2.55	1.26	—	16.7	7.4	99.2	97.8	95.4	38.0	14.1	11.1
	Fine sandy loam	A	4	—	1.36	—	—	—	—	—	—	—	—	—
	Very fine sandy loam	B	14	2.69	1.52	—	19.4	7.8	99.8	99.2	98.5	49.5	25.0	19.7
Fallbrook..... (Swale)	Fine sandy loam	A	1	—	1.36	—	14.8	7.2	99.1	97.6	95.2	42.9	15.6	13.1
	Fine sandy loam	A	10	—	1.53	—	13.4	7.2	—	—	—	—	—	—
	Very fine sandy loam	B	16	—	1.67	—	16.6	—	98.1	95.4	90.0	43.8	20.4	17.9
Las Flores..... (Side hill)	Loamy fine sand	A	0	2.58	1.45	1.63	6.5	6.2	100.0	99.9	99.9	23.6	8.7	5.2
	Very fine sandy loam	B	6	2.63	1.50	1.81	20.8	8.0	100.0	100.0	100.0	34.0	20.0	17.8
Merriam...... Bottom of hill)	Fine sandy loam	A	0	—	1.44	—	11.6	6.0	99.9	99.3	97.0	33.0	9.2	7.5
	Fine sandy loam	A	8	2.61	1.48	—	10.9	6.4	99.9	99.1	96.7	35.6	9.0	8.5
	Clay loam	B	20	2.67	1.64	1.92	25.3	7.4	100.0	100.0	99.9	58.0	42.7	40.6
Ramona ...... (Top of hill)	Loam	A	0	—	1.28	—	18.4	—	—	—	—	—	—	—
	Loam	A	4	—	1.40	—	19.4	—	—	—	—	—	—	—
	Clay loam	B	12	—	1.48	1.87	24.9	—	—	—	—	—	—	—
Ramona..... (Side hill)	Loam	A	0	2.50	1.25	—	17.6	7.7	97.6	95.9	92.5	52.3	16.9	14.4
	Clay loam	B	18	2.61	1.47	—	24.0	7.7	99.2	98.1	96.3	67.9	43.7	38.9

TABLE II—PERMEABILITY MEASUREMENTS OF THE VARIOUS SOILS

Soil and Location	Horizon	Depth of Sample (Inches)	Field Infiltration Capacity Rate (Inches Per Hour)		Laboratory Permeability Rates‡ (Inches Per Hour)	
			Range	Average	Range	Average
Fallbrook*	A	1	———	5.9	———	11.2
	A	2	———	—	30.6–36.0	33.3
(Ridge)	A	4	———	—	———	33.0
	B	14	0.2–3.0	1.9	4.0–16.4	10.2
Fallbrook*	A	1	8.4–24.4	16.4	———	—
	A	10	———	—	0.8–1.3	1.1
(Swale)	B	16	1.3–7.7	4.5	0.5–3.5	2.0
Las Flores† . .	A	0	8.1–10.1	9.1	39.5–54.1	46.8
(Side hill)	B	6	0.1–0.3	0.2	0.2–0.3	0.3
Merriam†.	A	0	———	119.0	4.9–39.1	22.0
(Bottom of hill) .	A	8	———	—	1.8–1.8	1.8
	B	20	0.1–0.3	0.2	0–0.01	0.004
Ramona*	A	0	0.9–43.6	11.4	6.2–20.2	13.2
(Top of hill). . . .	A	4	———	—	45.0–82.0	63.0
	B	12	0–0.2	0.1	0.2–4.5	1.7
Ramona* .	A	0	———	22.8	45.0–68.0	58.0
(Side hill).	B	18	———	0.1	0.1–0.3	0.2
Altamont. .		—	———	—	———	—

*Soil moist when field infiltration rates measured.

†Soil dry when field infiltration rates measured.

‡Undisturbed samples saturated from bottom for 24 hours, and permeability determined with distilled water under head of 25 centimeters, during third hour of run. Samples were 1½ inches deep and 2 inches in diameter.

The granitic bedrock, which was immediately below the B horizon, was undoubtedly a factor in the field test but not in the laboratory tests. The surface Las Flores soil, as shown by field test, is about 45 times more permeable than the subsoil, while for the laboratory test the ratio is about 160 to 1. Comparable ratios for the Merriam soil are: 600: 1 and 5500: 1, and for the Ramona clay loam 230: 1 and 290: 1. Such differences in permeability clearly indicate the probability of producing a water table immediately above the B horizon following the addition of water, either as rain or as an irrigation, in amounts in excess of that required to wet the soil to field capacity. With primary soils on steep slopes there is always the possibility of having water move down hill above the bed rock. Where no interrupting drains are present the seepage of water through the soil occupied by plant roots might continue for considerable periods. Not only is the soil in which the water table is present deficient in opportunity for aeration, but also the soil within the range of capillary rises is affected. This is clearly indicated by the data presented in Table III and Fig. 3.

Field observation indicates that unusually high amounts of organic matter on the ground surface are the rule in our avocado plantings. In the younger orchards permanent cover crops are common, and in the large, well shaded, orchards the ground is generally covered with a thick mat of leaves and twigs from the trees. Disregarding any other effects of such organic matter, it at least should accentuate the difficulty by increasing the permeability of the A horizon without a comparable increase in the permeability of the B horizon.

TABLE III—AVERAGE MACROPOROSITY AND MOISTURE CONTENT BY VOLUME AT VARIOUS TENSIONS

Soil and Location	Horizon and Depth (Inches)	Number of Observations	Average Macroporosity and Standard Error	Average Moisture Content of Soil (Per Cent by Volume)								
				pF 0	pF 0.50	pF 1.00	pF 1.20	pF 1.40	pF 1.60	pF 1.80	pF 1.90	pF 1.95
Fallbrook	A- 1	1	20.0	58.8	52.4	50.2	48.1	44.9	38.8	31.7	29.9	28.8
(Ridge)	A- 2	2	22.7 ±6.4	55.8	48.2	43.3	39.8	35.8	33.2	29.6	28.8	28.0
	A- 4	1	16.5	44.2	42.4	36.9	34.6	32.6	27.7	27.0	25.8	24.8
	B-14	4	8.1 ±0.8	38.8	36.5	35.9	34.5	32.9	30.7	28.4	27.4	26.8
Fallbrook	A- 1	2	17.2 ±1.0	55.4	49.8	47.4	45.8	43.1	38.2	31.4	29.6	28.2
(Swale)	A-10	2	15.3 ±0.5	44.8	40.6	38.4	37.1	34.0	29.5	25.0	23 2	22.1
	B-16	4	7.3 ±0.4	34.8	32.4	32.2	31.2	29.7	27.5	25.6	24.5	23.8
Las Flores	A- 0	4	13.4 ±1.3	48.8	44.3	42.8	41.9	40.4	35.4	25.8	22.8	21.2
(Side hill)	B- 6	4	4.1 ±0.7	38.9	38.2	38 0	37.2	36.4	34.8	31.8	31.1	30.4
Merriam	A- 0	2	16.5 ±1.0	47.8	45.4	42.2	40.8	36.2	31.3	26.6	24.4	23.5
(Bottom hill)	A- 8	2	13.0 ±5 6	43.8	39.0	37.8	36.2	33.3	30.8	26.9	24.9	23.6
	B-18	2	7.5 ±0 2	42.5	40.8	40.4	39.1	37.1	35.0	32.0	31.5	31.0
	B-20	2	2.0 ±0.5	35.0	35.0	35.0	34.9	33.8	33.0	32.0	31.7	31.3
Ramona	A- 0	2	15.4 ±6.4	48.5	41.0	37.8	36.2	34.6	33.2	31.0	—	—
(Top hill)	A 4	2	9.2 ±0.8	41.2	39.1	36.7	34.8	33.5	32.0	30.2	—	—
	B-12	4	3 7 ±0.3	39.8	38.9	37.9	37.0	36.6	36.2	35.2	—	—
Ramona	A- 0	4	12 0 ±1.4	44.4	39.4	36.8	34 7	33.6	32.4	30.9	—	—
(Side hill)	B-18	4	5.0 ±0.6	41.8	39.2	38.4	37 6	37.4	36.8	36.2	—	—

Soil permeability has been related to the so-called "non-capillary" porosity by Baver (1) and Nelson and Baver (7). Since such "non-capillary" porosity is largely within the range of moisture contents

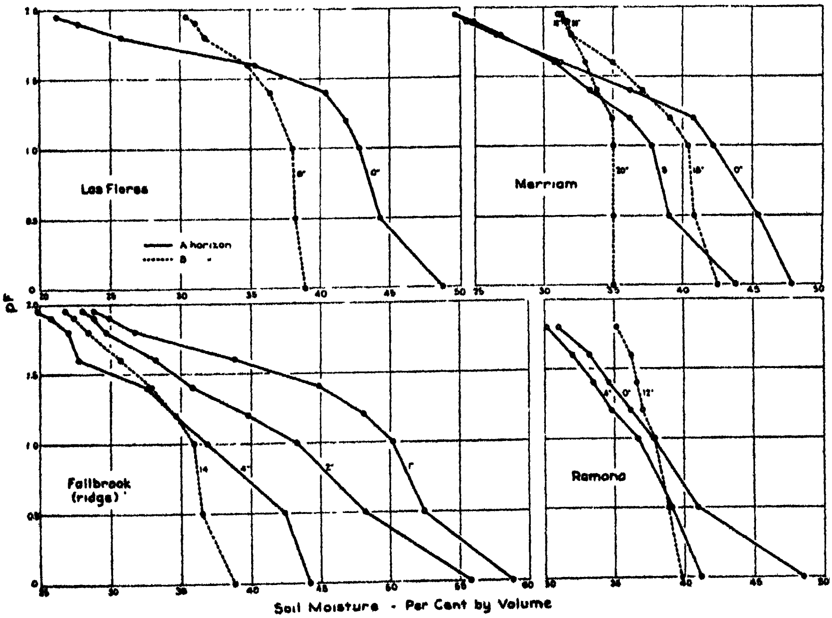

FIG. 3. Moisture—pF relationships.

accompanying capillary rise, the terms "macro pores" and "macroporosity" as suggested by Jamison (5) appear preferable and are used herein. The macro pores are essentially the larger pores between soil aggregates or particles which drain most readily, and are evaluated herein by investigating the equilibrium moisture retained in a soil under various increases in soil-moisture tension. The term pF proposed by Schofield (8) is used to express such tension. Macroporosity is herein defined as the per cent moisture by volume drained from a soil between pF 0 and pF 1.6, the volume of the soil as pF 1.6 being the basis. Selection of pF 1.6 is based on the work of Nelson and Baver (7), and substantiated by Baver and Farnsworth (2) and Jamison (5). Actually, permeability is an exponential function of the pore size, as shown by Nelson and Baver (7) ; so macroporosity, as here defined, cannot be perfectly correlated with the permeability of all soils. Shown in Table III are the macroporosity determinations for each soil, as well as the moisture by volume for the various pF values investigated. Comparison of Tables II and III will show the correlation between permeability and macroporosity.

For both the investigations of laboratory infiltration rates and moisture –pF relationships, undisturbed cores of soil were obtained in the field and brought to the laboratory without permitting them to dry out. They were 2 inches in diameter and 1½ inches deep. The samples were immediately wet from the bottom and left for 24 hours to saturate all readily available pore space. For the moisture –pF relationships an apparatus as described by Leamer and Shaw (6) was used.

CONCLUSIONS

Studies of some soils in which avocado trees have declined indicate well defined horizons which vary greatly in permeability. Differences in permeability between the surface soil and the subsoil were as great as 5500 to 1 for one soil. Under these conditions, water contents in excess of field capacity could easily prevail for considerable periods of time following heavy rains or large applications of irrigation water. Under such conditions, the data indicate that there would be very little opportunity for gas exchange in that portion of the soil normally most favorable for root activity. Further, the environment would be especially favorable for soil organisms associated with tree decline.

Macroporosity as herein used is the per cent volume of a soil drained between pF 0 and 1.6 (0 to 40 centimeters of water tension). Because this definition does not give increasing weight to increasing pore size, and no weight to the pores drained at a somewhat higher tension than pF 1.6, its use is only tentative. The macroporosity of a soil and its measurement appears to offer a more certain and definite method of determining the permeability and other related physical characteristics of undisturbed samples than do the commonly practiced methods.

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Oxygen and Carbon-Dioxide Changes in the Soil Atmosphere of an Irrigated Date Garden on Calcareous Very Fine Sandy Loam Soil[1]

By J. R. Furr and W. W. Aldrich, *U. S. Department of Agriculture, Riverside, Calif.*

IN the Southwest, basin flooding is a common method of irrigating date palms, and in some soils of low permeability the water may not disappear from the soil surface of the basins for several days after an irrigation. It would seem that such conditions might result in poor aeration of the soil and injury or retardation of growth of the palms.

In the summer of 1942 observations were made on the oxygen and carbon-dioxide content of soil air, the rate of date leaf elongation, and the appearance of date roots, in relation to soil moisture conditions in a date garden at the Martinez Indian Reservation, Indio, California.

Materials and Methods

The soil in this garden is a recent alluvial formation, classed as Indio very fine sandy loam, and from a depth of 2 or 3 feet to 8 feet the strata vary in texture from silty loam to coarse sand. Many sea shells occur throughout the profile, indicating a high calcium carbonate content, and except when wetted by irrigation water the sub-soil remains permanently dry. The retardation of water penetration is apparently effected near the soil surface, as the pore space in no part of the profile below 6 inches was found to be completely filled by water even when the soil surface was covered by water for several days at a time. The results of recent unpublished work carried on by the United States Regional Salinity Laboratory, Riverside, California indicate that retarded water penetration in this soil has resulted from the use of irrigation water which is low in total salt but in which the proportion of sodium to calcium and magnesium is high.

Eight plots, each consisting of one palm in a 30-foot-square basin, were established in a single row of palms. The odd-numbered palms were irrigated frequently, the even-numbered palms infrequently. As a measure of soil moisture conditions, moisture tension was determined with tensiometers, installed at depths of 6, 18, and 30 inches. The rate of date leaf elongation was determined by the method described by Moore and Aldrich (4).

Soil air samples were taken through permanently installed gas sampling wells of ⅛ inch copper tubing from depths of 6, 18, 30, and 96 inches, and analyzed in an apparatus of the Haldane type. Samples were withdrawn over acidulated 20 per cent NaCl solution at reductions in pressure below atmospheric usually amounting to only 10 or 15 inches of water, but sometimes, when the soil was almost saturated, amounting to 30 or 40 inches of water. Soil temperatures were obtained at 6-, 18-, and 30-inch depths with a recording soil thermograph. At the termination of the experiment roots were examined in trenches dug to a depth of 6 feet.

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[1] The writers appreciate the assistance of William A. Dollins in conducting the field work involved in this investigation.

RESULTS

The results obtained from plots under the same treatment were similar and may be illustrated by data from a single plot under each treatment.

The changes in percentage, by volume, of O_2 and CO_2 in the soil atmosphere at depths of 6, 30, and 96 inches and the variations in soil moisture tension at depths of 6 and 30 inches in plot 9–20 (infrequently irrigated), and plot 9–19 (frequently irrigated) are shown in Figs. 1 and 2. The values for O_2, CO_2, and moisture tension at the 18-inch depth were, in general, intermediate between those at 6 and 30 inches and, for simplification of the graphs, were omitted.

On plot 9–20 (infrequently irrigated) the usual summer irrigation schedule of two 6-inch applications of water per 3 weeks was adhered to in July and August. The split application was required because the basins held only about 6 inches at a time and about two days were required for the first application to disappear. Under this schedule the soil at 30 inches was kept at tensions well below that corresponding to the moisture equivalent, which Richards and Weaver (6) recently found to be equivalent to a tension of about 440 centimeters of water; and at the 6-inch level the tension varied from 11 to slightly less than 800, which in terms of water available for plant growth, may be considered relatively moist conditions (Fig. 1). When trenches were dug at the termination of the experiment the soil was found to be so dry below a depth of about 5 feet that it is doubtful if under the schedule of 12 inches of water every 3 weeks the soil was wetted below the 5-foot level all summer.

The soil moisture tension curves for frequently irrigated plot 9–19 (Fig. 2) show that from July 14 to the termination of the experiment on October 5, the soil in the top 30 inches was very wet. At the 6-inch level the tension dropped to almost 0 (1.5 to 10) while water was standing in the basins, and during most of the experimental period was below 100.

From the formula ($d = \frac{0.6}{h}$, in which d is the diameter of pore in centimeter, and h the height, at 25 degrees C, of the water column in centimeter) used by Nelson and Baver (5) for estimating soil pore size from the soil moisture tension, it may be calculated that soil pores with diameters of less than 3 millimeters, 0.6 millimeter, 0.06 millimeter, and .014 millimeter would remain filled with water at tensions of less than 2, 10, 100, and 440 centimeters of water, respectively. With these estimates as a basis it seems probable that a very large proportion of the pore space in the top 30 inches of soil of plot 9–19 was filled with water during the period of very frequent irrigations from August 19 to September 25, though the fact that it was possible to obtain gas samples, even with water standing on the soil surface for days at a time, indicates that all of the pore space was not filled by water. In sampling at depths below 6 inches, water was rarely withdrawn, but at 6 inches the gas samples were frequently drawn off as a chain of bubbles in a column of water, indicating that the gas obtained had been trapped in the large pore spaces.

Most investigations of soil aeration have been carried out in humid region soils which, in general, are neutral or acid, low in $CaCO_3$, and have permanently moist subsoils. The present investigation was carried

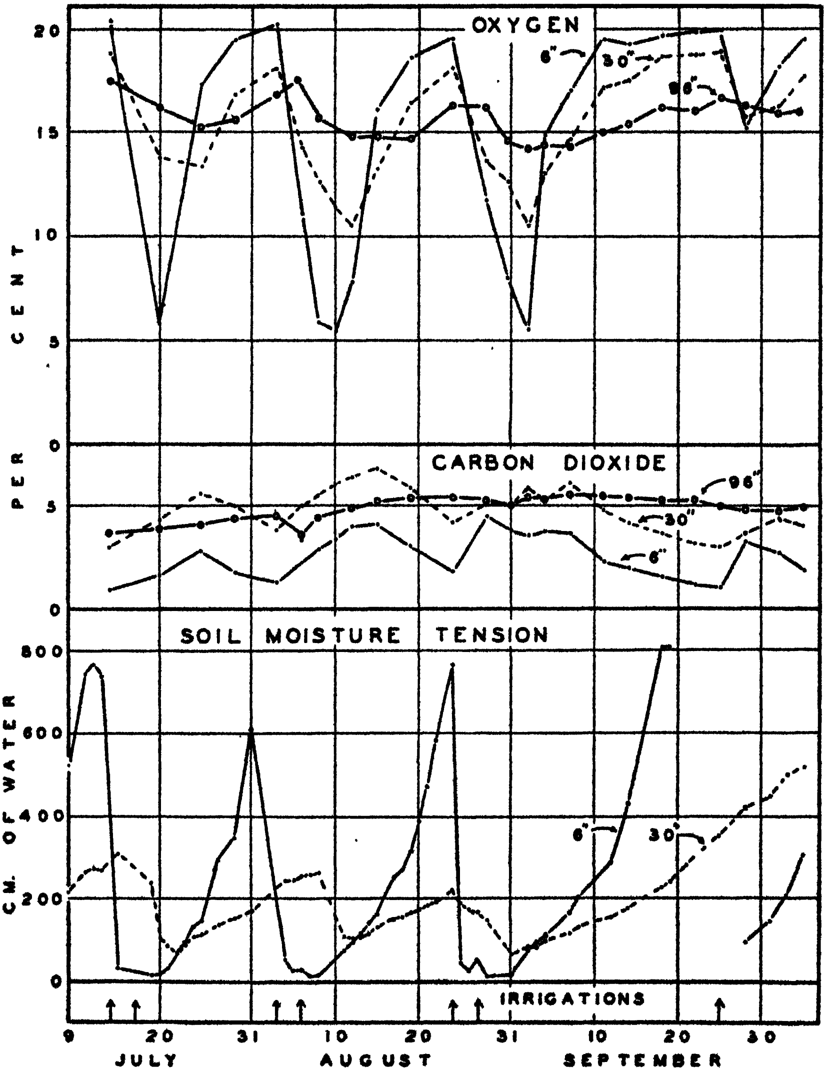

FIG. 1. The percentages of oxygen and carbon-dioxide in soil-air samples from depths of 6, 30, and 96 inches, and the soil moisture tension at depths of 6 and 30 inches in plot 9–20 (infrequently irrigated).

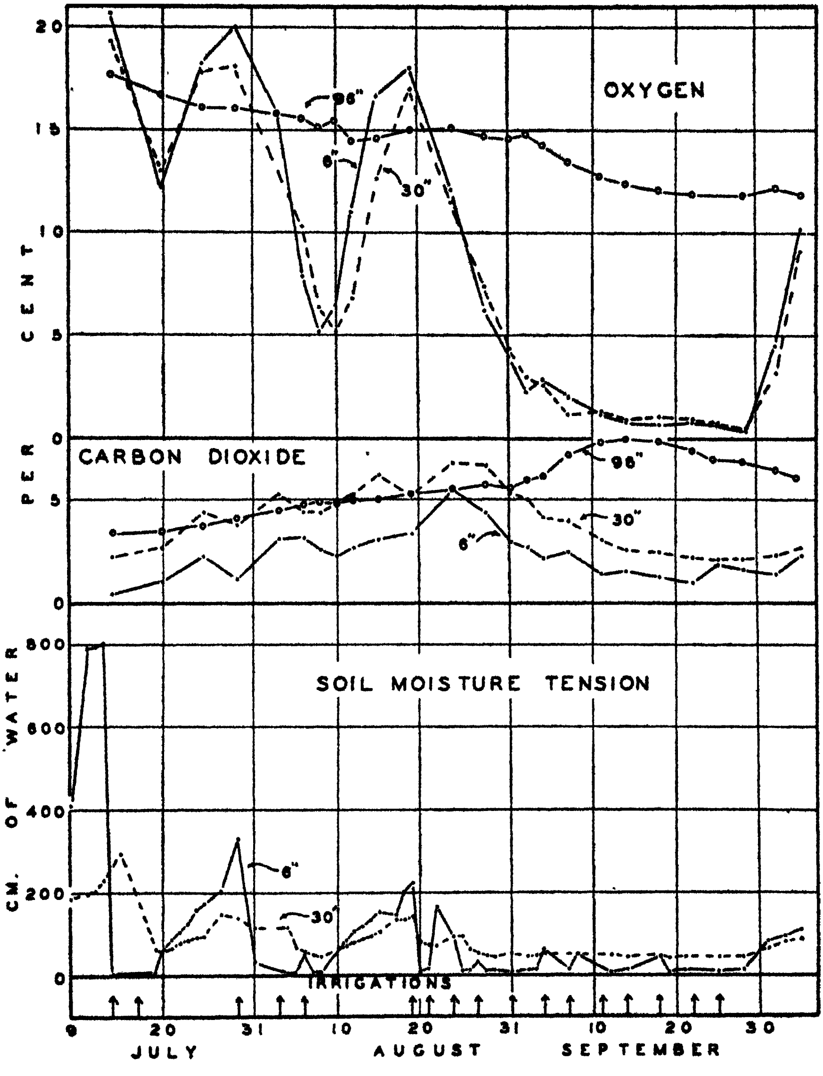

FIG. 2. The percentages of oxygen and carbon-dioxide in soil-air samples from depths of 6, 30, and 96 inches and the soil moisture tension at depths of 6 and 30 inches in plot 9–19 (frequently irrigated).

out on a soil representative of the desert or semi-desert soils which, in general, are alkaline in reaction when relatively free of CO_2, high in $CaCO_3$, and, except when wetted by irrigation water, have permanently dry subsoils.

The variations in O_2 and CO_2 percentage in relation to the variations in soil moisture are in some respects similar to and in others different from those reported for humid region soils, and these differences are apparently related to the differences in soil characteristics mentioned above.

The rhythmical changes in percentage of O_2 and CO_2 in plot 9–20, and during July and the first half of August in plot 9–19, as might be expected, are related to the changes in free pore space resulting from the wetting and partial drying of the soil. Unlike the usual condition in humid region soils, the percentage of O_2 reached relatively low levels in the top 30 inches and remained relatively high at 8 feet; but the CO_2 percentage, like that in humid region soils, in general increased with depth. Boynton (1) has called attention to the fact that in soil-air samples the sum of the O_2 and CO_2 percentages frequently deviate widely from the expected 20.8 per cent. The present results are striking in this regard. In some samples the sum of O_2 and CO_2 percentages was about 2. In comparison with the results usually found in humid regions those obtained on plot 9–19 during the period of frequent irrigations from August 19 to September 25 appear to be rather peculiar. The oxygen in the top 30 inches of soil decreased from 17 or 18 per cent on August 19 to 0.4 or 0.5 per cent on September 28, but the CO_2 increased for a short time to a maximum of 5 or 7 per cent on August 24 and then decreased to about 2 per cent on September 28.

The relatively stable, high level of O_2 at 96 inches is accounted for by the relatively dry subsoil and the low biological activity at this depth, and the general increase in CO_2 with depth probably resulted from the solution of CO_2 and the formation of bicarbonate in the slowly percolating irrigation water as it passed through the upper layers of soil, and the subsequent decomposition of the bicarbonate to normal carbonate with liberation of CO_2 to the gaseous phase as the soil moisture at the lower depths was extracted by the palms. This process probably accounts for the decrease in CO_2 percentage of the top 30 inches of soil and the increase at 96 inches in plot 9–19 during September when large amounts of water percolated through the upper 30 inches and the soil was wetted below 96 inches.

These results are of general interest in relation to the effect of partial pressure of CO_2 on soil reaction and on mineral nutrition of plants in calcareous soils which, it has been supposed, are rather low in CO_2. Bradfield (2) has recently called attention to the profound influence of the partial pressure of CO_2 on the pH of the soil solution and Breazeale and McGeorge (3) have emphasized the important effect of the CO_2 content of the soil-air on the absorption of mineral nutrients in calcareous soils. If it is assumed that the pH of this soil was largely determined by the $CaCO_3$–CO_2–H_2O system, then under the usual irrigation practice it may be supposed that the reaction of this soil was actually acid much of the time rather than alkaline, since according to Bradfield (2), at a temperature of 25 degrees C, the pH of a $CaCO_3$ suspension varies from 8.30 to 6.90 with variations in the partial pressure of CO_2 from 0.03 to 4.32 per cent.

Without adequate control of the partial pressure of CO_2, pH values obtained on samples of this soil in the laboratory would be of questionable meaning in relation to plant response. Even determinations made in situ, since it would be difficult to place the electrodes at various depths in the profile without affecting the partial pressure of CO_2 in soil at the electrode surfaces, might not represent true equilibrium conditions.

The mean soil temperatures at 6 to 30 inches varied from about 84 to 88 degrees F from July 14 to August 24, and then gradually decreased to about 76 degrees F in early October. Any effects of variation in soil temperature on the variations in O_2 and CO_2 appear to have been obscured by the effects of soil moisture, though it may be supposed that at such high temperatures biological activity would be high, and that the rapidity of change in percentage of O_2 in the upper 30 inches of soil was in part related to the high soil temperature.

As an index of the possible effect of deficient oxygen supply on water absorption by the roots of palms in the frequently irrigated plots, the rate of leaf elongation of the palms under each treatment was determined. The difference in average rate of elongation during the period of greatest difference in O_2 percentage (September) was less than 0.5 centimeter per day, and was probably not significant. It may be concluded therefore, that water absorption by the palms in the frequently irrigated plots was adequate for normal growth in spite of the greatly reduced O_2 content of the soil air. While it is possible that absorption by roots in the 6- to 30-inch zone was inhibited or reduced during the period of low oxygen level, and that the roots below 30 inches provided the palms with an adequate supply of water, this seems unlikely since the highest concentration of rootlets was found in the top 3 feet, and Moore and Aldrich (4) working with the date in similar soil found that soil moisture shortage in the top 3 feet resulted in greatly reduced leaf growth.

Roots were examined in 6-foot deep trenches in plots 9–20 and 9–19 on October 5 and 6. A larger number of discolored or dead roots were found in plot 9–19 than in plot 9–20, but most of the roots in both plots appeared to be uninjured, and in each, numerous roots which appeared to be in an active state of growth were found. It is possible that in plot 9–19 new root growth started after the O_2 percentage had risen appreciably above the low level maintained during most of September, but there is no information available on the minimum oxygen requirement for date root growth, and it must be supposed that such quick recovery, if such was the case, indicates that any injury sustained during the period of low O_2 content of the soil air was not severe.

SUMMARY

The variations in percentage of O_2 and CO_2, the soil moisture tension, and the rate of leaf elongation were determined in frequently and infrequently irrigated plots in a date garden on calcareous soil. The percentage of O_2 in the top 30 inches of soil varied widely with changes in soil moisture tension. The continuance of a 0.4 to 2 per cent O_2 level for 3 weeks did not result in measurable injury to the date palms.

Under the customary irri[redacted] content, 1 to 6

per cent, in the soil atmosphere was high enough to affect appreciably the reaction of a calcareous soil.

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Effect of Oxygen Pressure in Aerated Nutrient Solution on Production of New Roots and on Growth of Roots and Tops by Fruit Trees

By DAMON BOYNTON and O. C. COMPTON, *Cornell University, Ithaca, N. Y.*

A PRELIMINARY study made in 1940 (1) indicated that production of new roots by apple tree root systems might be seriously retarded when the oxygen level of the soil air decreased relatively little, at least when the carbon dioxide level was raised correspondingly. Under the conditions of that experiment, it was impossible to control oxygen and carbon dioxide levels independently of each other, and there was some question as to whether the oxygen percentages recorded represented the partial pressures actually in equilibrium with the roots. This paper is a report on somewhat more carefully controlled studies designed to eliminate some of the weaknesses and check observations of the original work.

GENERAL PROCEDURE

The nutrient solution tanks used and the methods of aeration are diagramed in Fig. 1. Gas mixtures were made up by filling the gas drums with water and then introducing air, cylinder nitrogen, carbon dioxide, or oxygen at atmospheric pressure as the water level was dropping in the drums. It was possible to keep deviations from the desired gas mixtures to within ± 1 per cent of gas volume, except when carbon dioxide was used in the mixture. One gas reservoir

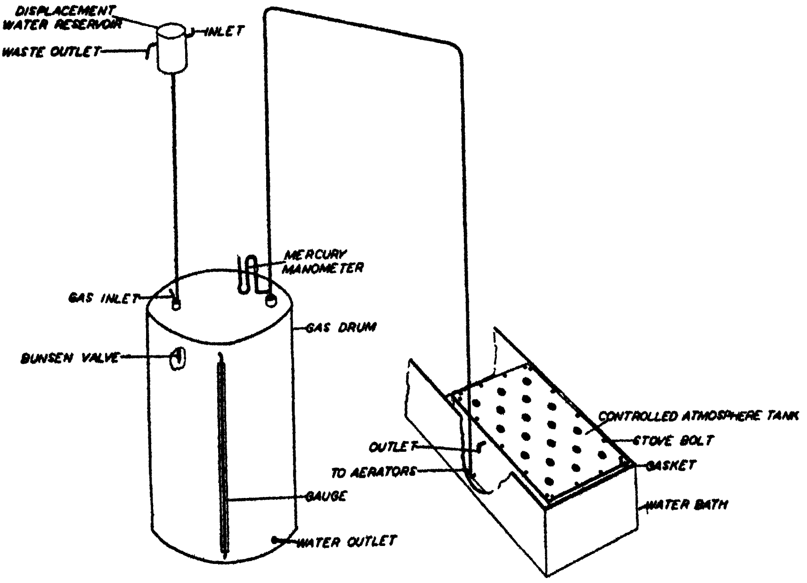

FIG. 1. Diagram of aerating system used in the study.

served one nutrient tank. After a gas mixture was made up, the drum was closed except for the water inlet and the outlet to the sintered glass aerators in the nutrient tank. As water entered the drum, the gas pressure increased until it was sufficient to overcome the resistance in the aerators. The maximum pressure obtainable under constant temperature was determined by the height of the water inlet. A Bunsen valve at the bottom of the water inlet in the drum prevented greater pressure in the reservoir (created by rising greenhouse temperature) from blowing out the hydrostatic head.

The flow of gas necessary to maintain equilibrium of the nutrient solution with the gas mixture depended mostly on the amount of respiring root surface and on the temperature of the nutrient solution. With the nutrient solution temperature held close to ± 5 degrees of 63 degrees F by the water bath the rate of gas flow was determined largely by the former consideration. In run 1, with six trees in a nutrient tank, six to eight aerators and 2 to 3 cubic feet of gas per 24 hours were satisfactory. In run 2, with 18 trees per tank, 12 aerators and 6 to 12 cubic feet of gas per 24 hours were found necessary. In both runs the nutrient tanks aerated with high-oxygen mixtures were harder to keep at equilibrium than those aerated with low oxygen mixtures. Since the success of the experiment depended on maintenance of equilibrium conditions, the nutrient solution was analyzed for dissolved oxygen frequently and gas flow was adjusted if necessary. In run 1, the determination was made with a Van Slyke blood gas outfit (3) ; in run 2 the Lund micro-Winkler method (2) with slight modification was used.

The trees were allowed to grow in tap water for 2 weeks. Hoagland's solution, modified somewhat, was used as the nutrient medium after the first 2 weeks of both runs. The solution was changed in each tank once a week in run 1 and once every 2 weeks in run 2. During the period of changing, the root systems were first exposed to air for a few moments and then placed in fresh solution saturated with air. In some instances a period of 6 to 8 hours elapsed after the new solution was introduced before the low-oxygen tanks had gotten down to dissolved oxygen levels in equilibrium with the aerating gas.

Run 1. Special Procedure and Results:—Uniform 1-year-old budded McIntosh/Malling XII trees,[1] were used. The trees had been fall dug and stored in a nursery cellar. The roots were washed, all rootlets smaller than two millimeters diameter at the point of origin were removed and the remaining roots were cut back to between 3- and 6-inch lengths. The tops were cut back to two buds. Six trees were sealed into the tops of each of 10 nutrient tanks which were aerated with the gas mixtures shown in Table I.

The tanks were sealed and aeration with these gas mixtures was started on February 10, 1941. Bud swelling occurred almost at once and some buds had broken a week later. Only one shoot per tree was allowed to grow. On February 19 some root development had occurred with most new roots appearing in the high oxygen tanks. There was

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[1] Supplied by Dr. H. B. Tukey, New York State Agricultural Experiment Station, Geneva, N. Y.

TABLE I—GAS MIXTURES USED IN RUN 1

Tank Number	Aerating Gas Mixture		Tank Number	Aerating Gas Mixture		
	Per Cent O_2	Per Cent N_2		Per Cent O_2	Per Cent CO_2	Per Cent N_2
1 A	5	95	—	—	—	———
2 A	10	90	1 B	5	10	85 5 weeks
3 A	15	85	——	—	Air	3 weeks
4 A	Air		—	—	—	———
5 A	Air		2 B	10	10	80 8 weeks
			3 B	15	10	75 8 weeks
			4 B	20	10	70 8 weeks
			5 B	—	Air	———

no apparent influence of the aerating gas mixture on time of development of the buds or on the initial shoot growth. It was not until the shoots were several inches long that such effects were noticeable. The experiment was concluded on April 3, 1941.

Figs. 2, 3, and 4 summarize some of the most important data on tree response for the six tanks aerated with mixtures of air and nitrogen. The great solubility of carbon dioxide in the displacement water under pressure made it impossible under the circumstances of the experiment to prevent the carbon dioxide percentage of the gas mixture from fluctuating greatly so that the data on tanks 2 B, 3 B, and 4 B are not presented.

The figures show that there was a pronounced effect of the oxygen pressure in the aerating gas mixture on number and weight of new roots, and on top growth.

That the effect of low oxygen pressure on production of new roots is a direct one and that subjection to low oxygen environment for more than a month may cause no permanent inhibition of root initiation are indicated by the following observation: Tank 1 B was aerated with a gas mixture containing about 5 per cent O_2, 85 per cent N_2, and 10 per cent CO_2 for 5 weeks. At the end of that period, the average number of roots was three in the tank 1 B and five in tank 1 A. For the following 3 weeks tank 1 B was aerated at the same rate of flow with air. The average number of roots per tree increased in that short period of time to 41 whereas in tank 1 A there was no increase in root number.

Run 2. Special Procedure and Results: — Uniform 1-year-old McIntosh budded on seedling, Italian prune on Myrobalan, and Elberta peach on seedling stocks

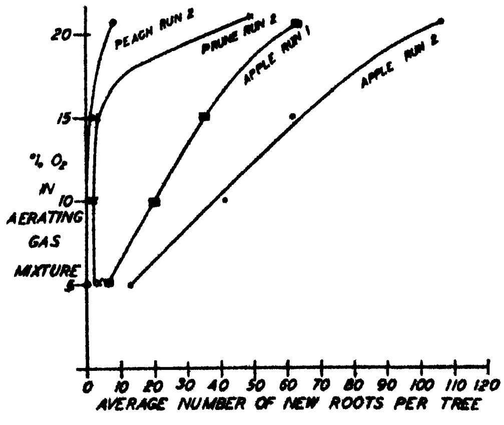

FIG. 2. Relation between per cent oxygen in aerating gas and average number of new roots per tree.

TABLE II—DISTRIBUTION OF SPECIES AND THE AERATING GAS MIXTURES USED IN RUN 2

Tank Number	Number of Trees			Per Cent O_2	Per Cent N_2
	Apple	Prune	Peach		
4	18	0	0	Air	
9	18	0	0	15	85
2	18	0	0	10	90
5	6	6	6	No aeration*	
6	6	12	0	Air	
1	6	12	0	15	85
10	6	12	0	10	90
7	6	0	12	Air	
3	6	0	12	15	85
8	6	0	12	10	90

*Oxygen dissolved in solution of tank 5 was equivalent to that in equilibrium with an atmosphere containing about 5 per cent oxygen most of the time.

were used. The trees were fall dug and were heeled in outside until January. They were then taken up, the roots were washed, all rootlets smaller than 2 millimeters at the point of origin were removed and the other roots were cut back to 2 to 4 inches in length. The tops were cut back to two buds. Eighteen trees were sealed into the tops of each of 10 nutrient tanks. Table II shows the distribution of species and the aerating gas mixtures used in the different tanks.

The tops were sealed to the tanks and experimental aeration was started on January 28, 1942. By January 31 the buds of all the trees were obviously swelling. As the shoots developed only one was left on each tree. There were no obvious effects of the differences in aeration on the top growth of the trees until the shoots were an inch or more long. The experiment was concluded on March 14, 1942. Figs. 2, 3, 4 summarize some of the more important data on root and top growth.

The figures show that there was a pronounced decrease in new root production and top growth when the oxygen pressure of the gas in

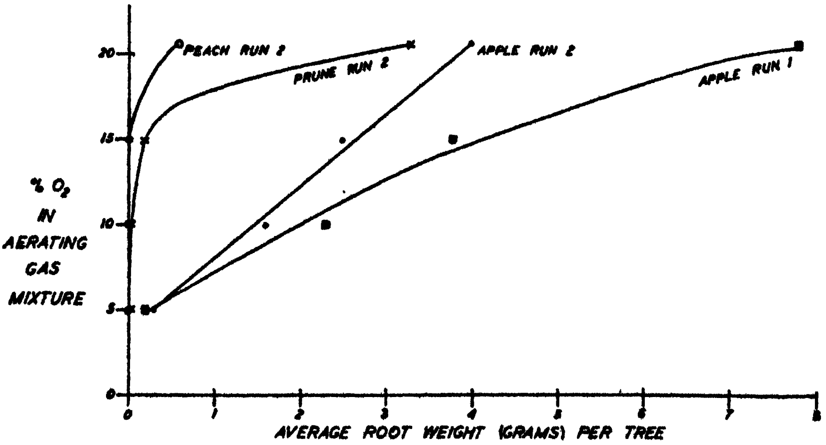

FIG. 3. Relation between per cent oxygen in aerating gas and average root weight per tree.

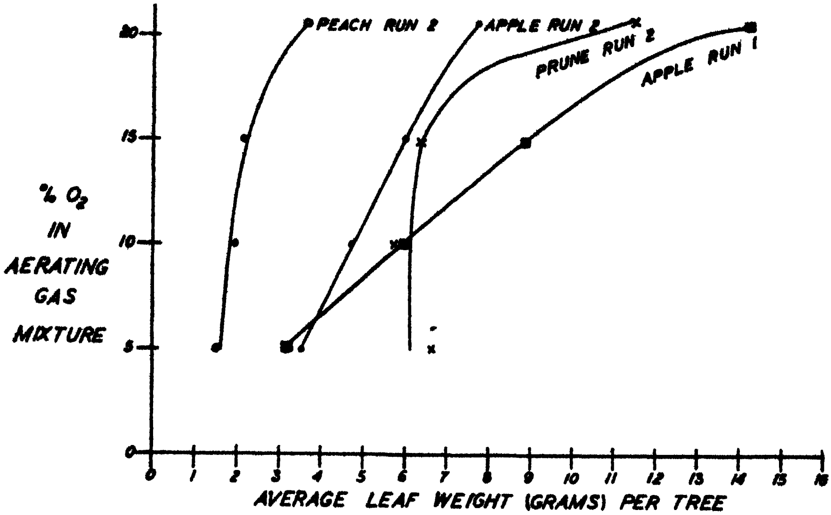

FIG. 4. Relation between per cent oxygen in aerating gas and average leaf weight per tree.

equilibrium with the nutrient medium was decreased below the O_2 pressure of air.

GENERAL DISCUSSION

The following points of interest are indicated in Figs. 2, 3, 4 in which some of the more significant data are graphed.

At a given oxygen level the average number of roots produced by apple trees was greater in run 2 than in run 1. But at any of the higher oxygen levels the average root weight and leaf weight of apple trees were greater in run 1 than in run 2. The reason for the differences in root number is not apparent. But run 1 extended over a period of 54 days, whereas run 2 lasted for only 45 days; and that may have accounted for the fact that in run 1 a lesser average number of roots produced more root weight and leaf weight than a greater number of roots produced in run 2. However, there is nothing in the data to indicate that the relative disadvantage of the root systems aerated with low oxygen gas mixtures was overcome by time; in fact the opposite is suggested. Thus, a decrease in oxygen in the aerating gas from 20.8 per cent (air) to 15 per cent resulted, in run 1, in a decrease of average root number to 56 per cent, in a decrease of average root weight to 58 per cent and a decrease of average leaf weight to 62 per cent of maximum, whereas the same decrease in per cent oxygen resulted in run 2, in a decrease of average root number to 62 per cent, of average root weight to 64 per cent and of average leaf weight to 78 per cent.

Considering the curves for run 2 separately, it is apparent that at a given oxygen level the number of roots, and weight of roots produced by the apple trees were greatest and those figures for the peach were least. But whereas there seemed to be almost a simple linear increase in number and weight of apple roots with increasing oxygen pressure, the average number and weight of peach and prune roots remained very small in all tanks except those aerated with air. In spite of the greater amount of new root surface on the apple trees, the shoot growth and leaf weight produced by the prune trees was greater than that of apple trees under comparable conditions. However, there were no significant differences in leaf weight among the prune trees in the tanks with restricted oxygen aeration, whereas the leaf weight of the apple trees increased significantly with improved aeration in much the same way that the production of new roots was affected. The average peach tree leaf weight was far less than that of either apple or prune under comparable conditions, and even the trees in tanks aerated with air appeared somewhat lacking in vigor.

Conclusions

More work must be done before the quantitative relative effects of different oxygen pressures in the rooting medium on root production, root growth, and top growth by fruit trees can be evaluated with certainty. Under the conditions of the present study, a decrease in oxygen pressure of the gas continuously in equilibrium with the rooting medium to three-quarters of that found in air caused marked decreases in the number and weight of new roots and in the top growth produced by apple, prune, and peach. These effects were produced without appreciable increase in the carbon dioxide pressure in the rooting medium above that in air. Whether or not high carbon dioxide pressures accompanying low oxygen pressures in the nutrient would have changed the behavior of the trees is a subject requiring further study.

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Effect of Ground Water Table on Apparent Photosynthesis and Growth of Apple Trees

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Abstract

This will be published in full in an Ohio Agricultural Experiment Station Bulletin.

THE project was initiated in May 1941 and continued through the growing season of 1942. When the experiment was started, the root systems of six 5-year-old Stayman Winesap apple trees were surrounded vertically in 10-foot squares with galvanized sheet iron to a depth of 30 inches. An impervious hardpan at a depth of 30 inches served as a bottom for each tree compartment. An automatic watering system maintained the water at the desired depths. The following treatments were maintained the two seasons from the time of budding until leaf drop:

Tree A^1: Check — received water only from rains (used in 1941 only).
Tree A: Water table held 10 inches from soil surface.
Tree B: Check — received water only from rains.
Tree C: Flooded from May 1 to June 8, 1941.
Tree D: Check — received water only from rains.
Tree E: Water table 20 inches from the soil surface.

During the growing season of 1941 there was no significant difference between the photosynthetic and transpiration activity *per unit leaf area* of trees A^1, A, B, D, and E. Tree C, however, which was flooded for 5 weeks in early spring was significantly lower than its check. Total linear growth and total leaf area of the individual trees at the end of the first season ranked as follows: A, E, B, D, with tree C definitely the lowest.

In April 1942 tree C bloomed heavily with 3,483 blossoms; tree A — 2,028; tree A^1 — 932; tree D — 594; tree E — 376; and tree B — 333 blossoms. On August 22, tree A had the most fruits (79); the other trees ranked in the following order: D, A^1, E, B, and C last with only 12 fruits. All fruits on tree C showed considerable cracking with fairly poor color at an early date. Percentage of water in the fruit from tree C was significantly the lowest. Fire blight was greatest on the tree supplied with an abundance of water — tree A.

The relationship between trees on the basis of total leaf area and shoot growth in 1942 was in the same order as in 1941. However, photosynthetic activity per unit area of leaf surface was relatively better for tree C in 1942 than in 1941, but slightly under the level maintained by the other trees. Although the foliage on tree C was a normal green in 1942, its general recovery and appearance was definitely weak. The tree probably will not regain normal vigor for 3 to 5 years from the flooding treatment in 1941.

The experiment will be continued in a similar manner in 1943, except that the 10-inch and 20-inch ground water levels for trees A and E will be lowered to a 30-inch depth about the middle of July.

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Response of Apple Trees to Potash in the Champlain Valley III

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PREVIOUS reports in this series (1, 2) have shown marked though incomplete control of a form of leaf-scorch and improved terminal growth of McIntosh apple trees as a result of the application of potassium fertilizers to the soil. One test showed prompt benefit from potassium sulfate sprayed on the foliage. The present contribution contains further results of the experiments previously described and a few general observations on the possible place of potassium in the soil-management program of Champlain Valley orchards.

FOURTH YEAR RESULTS IN EXPERIMENT I

This experiment involves four pairs of badly stunted McIntosh trees planted in 1930 in a highly infertile piece of Coloma fine sandy loam soil. All trees have received a moderate annual application of ammonium sulfate. The annual treatment of one of each pair of trees has been to dig into the soil in a narrow band beneath the tips of the branches, 3 pounds of fertilizer-grade K_2SO_4. In the second year of this treatment, (1940) leaf-scorch was strikingly reduced and in the third year, was almost, but not entirely eliminated. Terminal growth was increased the third year. Some results following the fourth annual treatment are given in Table I, which supplements Table I of last year (2).

TABLE I—FOURTH-YEAR EFFECT OF POTASSIUM TREATMENTS ON TERMINAL GROWTH, LEAF INJURY, AND LEAF-COMPOSITION OF PAIRED McINTOSH APPLES

Location		Annual Soil Treatment 1939–1942	Fertilizer Injury to Leaves	Mean Growth Per Terminal (Inches) 1942	Composition of Shoot Leaves July 27, 1942	
Row	Tree				Per Cent Ash	Per Cent K
71	27	None	None	12.0	5.94	1.01
71	28	K	Some	13.8	7.06	2.40
72	27	None	None	7.9	6.12	0.76
72	26	K	Some	15.9	6.64	2.08
72	28	None	None	8.2	5.75	1.16
72	29	K	None	17.8	6.22	1.83
73	26	None	None	4.0	5.49	0.68
73	28	K	Some	13.1	6.63	1.95

Three features mark the fourth year of this experiment. Potassium deficiency leaf-scorch disappeared completely from the treated trees, but the checks were not as severely affected as formerly. Terminal growth averaged about twice as much on the treated as on the untreated trees this difference being almost as great as in 1941. Injury that appears to be associated with application of potassium as the commercial sulfate or muriate fertilizer, was noted in the form of a leaf-scorch dissimilar to that caused by potassium deficiency. The principal symptom is late-season scorch of the leaf blade between the large veins. Where present, it was largely restricted to a few branches per tree.

Although these four treated trees have shown marked improvement as exemplified by elimination of leaf-scorch and improved growth, they still are not first-class trees. The relatively small amount of live vigorous wood encasing the winter-injured hearts may be responsible for their restricted recovery. The apparent fertilizer injury also may be involved. The treatments have been much heavier and restricted to a narrower band of soil than would be usual in commercial practice.

Second Year Results in Experiment II

This section deals with the experiment started in 1941 with 6-year-old McIntosh trees in which leaf scorch was reduced the first year of treatment by potassium fertilizers, the benefit being similar whether the material was muriate or sulfate, placed on the surface, or dug in, extremely or only moderately concentrated, or sprayed on the foliage six times as a 1 per cent solution of K_2SO_4. These trees which are in sod, received an average of about 2 pounds of ammonium sulfate apiece in 1941 and 1942, the exact amount depending on size of tree. The treatments in 1942 were identical with those of 1941 except that five instead of six spray applications with 1 per cent K_2SO_4, were made. Table II contains a summary of treatments and results.

TABLE II—Second-Year Effect of Various Annual Treatments on Potassium-Deficiency Leaf Scorch, Terminal Growth and Leaf Composition (1942)

Treatment*	Number of Trees	Mean Per Cent of Scorch Early September	Mean Terminal Growth (Inches)	Composition of Shoot Leaves§ July 27	
				Per Cent Ash	Per Cent K
V. No potassium	9	54	10.7	5.99 5.26	0.56 0.58
IV. K_2SO_4 spray, 1 per cent solution†	9	0	12.8	6.74 6.72	1.16 1.56
I. KCl Surface, 5-foot circle‡	8	0	12.6	7.27 7.13	1.95 1.92
II. K_2SO_4 Surface, 5-foot circle‡	8	0	14.0	7.23 6.78	1.70 2.18
III. KCl-surface, 10-foot circle	9	0	13.2	6.75 6.97	1.68 2.17
VI. K_2SO_4 dug in, 5-foot circle	8	0	17.3	6.91	1.55
VII. KCl dug in, 5-foot circle	9	0	16.5	6.87 6.54	1.58 1.56

*All soil applications were made April 28, 1942. The material was spread evenly over the entire area of a circle of the diameter indicated.

†Five sprays averaging 2 gallons per tree were made between May 9 (bloom not quite full) and July 3; fertilizer grade K_2SO_4.

‡KCl is muriate of potash, 60 per cent K_2O, applied at the rate of 2 pounds, 6 ounces per tree wherever used.

K_2SO_4 is fertilizer grade, 48 per cent K_2O, applied at the rate of 3 pounds per tree except in spray.

§First figure of each pair represents analysis of a composite sample of 100 leaves from the first four trees getting the treatment. Second figure is for a comparable sample from the next four trees.

Potassium-deficiency leaf-scorch was eliminated in all 51 of the trees that received potassium in any form, while it was present in 8 of the 9 trees not getting potassium. The average per cent of leaves affected on the checks was 54 about September 1 compared with 50 in 1941 and 56 in 1940. The potassium treatments appeared to have improved terminal growth slightly in 1942, the second year.

Only about half as many of the leaves of untreated trees showed potassium-deficiency scorch (average of 24 per cent) on June 26, 1942, as in early September. A high, though unknown, percentage of the terminal growth had taken place by June 26. The fact that potassium deficiency as indicated by leaf scorch and by leaf-content of potassium usually does not become very acute until late summer, perhaps explains why terminal growth is not more strikingly affected.

Five of the treated trees showed some intercostal leaf-scorch of the type regarded as due to excessive use of potassium fertilizers in Experiment I. One such tree was in treatment No. I, two in treatment No. II, and two in treatment No. III.

GENERAL OBSERVATIONS AND THE PLACE OF POTASSIUM IN THE CHAMPLAIN VALLEY FERTILIZER PROGRAM

The generally higher level of potassium shown in this paper as compared with the levels of former years (1, 2), may be due, in large part, to an earlier date of sampling; a somewhat better distribution of rainfall also may have contributed. The per cent ash was higher wherever potassium was applied, than where it was not.

The etiology of the injury associated with applications of potassium fertilizers in the two experiments is obscure. In Experiment I, it occurred on trees that had received K_2SO_4; in Experiment II, what appeared to be the same symptom occurred both on trees that had received K_2SO_4 and on those that had received KCl; in neither did it appear on an untreated tree. In 1941, a somewhat similar symptom of injury was noted on some trees that had been given heavy, concentrated mid-summer fertilization with KCl. Further work is required to show whether it is due to an excess of K, to a deficiency of some other nutrient element brought about by high K, to an excess of the sulfate or chloride anions, to an excess of total salts, to root injury, or to some other cause. The K-content of some of the composite leaf-samples is very high, though not above that sometimes found in trees free from injury-symptoms. The injury usually is pronounced on the leaves of just a few branches per tree. The method of sampling would not reflect the situation in these branches, because the policy was to avoid scorched leaves so far as possible, and because in Experiment II, each sample was a composite from four trees not more than one of which ordinarily showed injury symptoms.

Analyses of shoot leaves from random trees in orchards throughout the state in 1941 (3) showed a lower average level of potassium in the Champlain Valley than in the Hudson Valley or the Lake Ontario fruit district. Until 1942, leaf-scorch from potassium deficiency in the Champlain Valley was largely confined to young, non-bearing trees, or trees just commencing to bear. This year, it was noted on scattered trees in at least six mature orchards of the region. The affected trees were not on any single soil type, but in some cases, were on soils not ideally suited to fruit growing. In all orchards where this leaf-scorch occurred, the practice for many years, has been to apply nitrogen without other nutrient elements, aside from those contained in infrequent or very light treatments of hay mulch or manure.

While these observations suggest that consideration be given to potassium in the soil-management program of mature Champlain Valley orchards, it has not yet been shown experimentally, that potassium treatments will increase the yield of orchards in the region. The leaf-scorch symptom in most of these bearing orchards has been only slight, and its occurrence may have been associated with some vagary of the weather. If so, it may disappear. On the other hand, it is possible that many orchards are approaching a condition in which addition of potassium will be necessary. The apparent ease with which trees take in quantities of potassium in excess of those used in normal processes and the possibility of injury from repeated heavy treatments, suggest that heavy annual applications may be neither necessary nor desirable, once control of potassium-deficiency scorch has been attained. An important reason why many Champlain Valley orchards do not have a potassium problem is the common practice of using liberal quantities of dairy-barn manure or hay mulch, or both.

SUMMARY

In one experiment, leaf-scorch from potassium deficiency was completely eliminated after the fourth annual treatment and in another, after the second. In both experiments, the potassium content of shoot leaves appears to have been raised to a level above that needed for normal functioning. The repeated heavy application of potassium fertilizers to the soil appears to have produced a limited amount of foliage injury, the exact origin of which is obscure. Formerly restricted to young orchards, leaf-scorch from deficiency of potassium made its appearance on occasional trees in a number of mature orchards of the region in 1942. More experimentation is needed before it can be said whether or not it would be profitable to use potassium fertilizers in these or other mature Champlain Valley orchards.

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Results of Preliminary Tests on Correction of Potassium Deficiency in Tung

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DURING the month of July, 1941, a striking disorder of tung foliage became prevalent in southern Georgia, and adjoining areas of western Florida. The general occurrence and severity of the disorder were such as to cause considerable anxiety. This was true especially because it occurred mostly in orchards on heavy soils of the Red Bay type, which are cônsidered to be the best tung soils. Members of the staffs of the United States Field Laboratories for Tung Investigations at Cairo, Georgia, and at Gainesville, Florida, made detailed observations on the affected trees. The general concensus was that the trouble must be a deficiency, either of magnesium, calcium, nitrogen, or potassium. Samples of leaves from affected and from normal trees in the same general area were analyzed and the data (1) showed that the disorder was associated with a low potassium content in the leaf tissue.

Even though it was very late in the season, small plots were set up at the same time that the leaf samples were taken to determine whether the trouble could be corrected by the application of various mineral salts. As was anticipated, the leaves were killed by frost before there was any evidence that the disorder had been corrected by any of the treatments. In 1942, the treatments were modified in view of the evidence then available from leaf analyses. The same trees in the same plots had to be used because they were the only trees in the field that had been previously scored, and consequently, were the only ones positively known to have had the disorder in the fall of 1941. Changes were made in treatments A, B, G, H, J, and K (Table I). These treatments in 1941 had involved the application of magnesium, either as Epsom salt, or as dolomite, or calcium in the form of hydrated lime. It was felt that any carry-over effect would be negligible, nevertheless the modifications were made in the plots which had originally received the lower amounts of the several materials. The substitutions in 1942 consisted principally of the inclusion of nitrogen or phosphorus, and in the use of potassium carbonate (treatment B) as an additional source of potash. Modification in amount used was made in treatment C by reducing the amount of Epsom salt from 5 pounds to one pound; in treatment F by increasing the amount of muriate of potash from 3 pounds to 5 pounds; and in treatment I by reducing the amount of dolomite from 10 pounds to 5 pounds. Table I shows the complete list of treatments these trees received in each year.

All the treatments were used as supplements to a basic application of 4 pounds per tree of the 3–6–7 mixed fertilizer used on the entire orchard. In 1941, when the experiment was begun, the deficiency pattern appeared in two distinct types. In one type the affected portion of the leaf was chlorotic (1) and in the other, areas in a similar pattern

TABLE I—EFFECT OF TREATMENTS ON CONDITION AND POTASSIUM CONTENT OF FOLIAGE, AND ON SHOOT GROWTH OF TUNG TREES (CAPPS, FLORIDA 1942)

Treatment Designation	Fertilizer Applied Per Tree in Addition to Basic Application		Necrotic Series						Chlorotic Series				
			Foliage Score* November 4, 1942				K in Leaves Dry Basis (Per Cent)	Average Shoot Growth Per Tree (Cms)	Foliage Score November 4, 1942				K in Leaves Dry Basis (Per Cent)
	1941‡	1942†	Replication 1	Replication 2	Replication 3	Total			Replication 1	Replication 2	Replication 3	Total	
A	1 lb Epsom salts	2 lbs muriate of potash 2 lbs hydrated lime	1	0	3	4	0.69	194	0	0	0	0	0.74
B	2 lbs Epsom salts	1 lb potassium carbonate	1	0	2	3	0.62	201	0	0	0	0	0.70
C	5 lbs Epsom salts	1 lb Epsom salts	4	5	4	13	0.50	159	0	3	1	4	0.47
Check	None	None	5	2	5	12	0.50	164	1	3	1	5	0.47
D	1 lb muriate of potash	1 lb muriate of potash	0	1	2	3	0.74	184	0	1	0	1	0.48
E	2 lbs muriate of potash	2 lbs muriate of potash	0	0	2	2	0.74	241	0	0	1	1	0.74
F	3 lbs muriate of potash	5 lbs muriate of potash	0	0	0	0	0.92	208	0	0	0	0	0.80
Check	None	None	2	1	2	5	—	112	1	1	1	3	—
G	2 lbs dolomite	3 lbs potassium nitrate 14-0-44	0	0	0	0	0.85	703	0	0	0	0	0.82
H	5 lbs dolomite	3 lbs 20 per cent superphosphate	2	0	2	4	—	219	0	0	1	1	—
I	10 lbs dolomite	5 lbs dolomite	1	1	2	4	0.61	270	4	0	2	6	0.49
Check	None	None	1	3	1	5	—	160	3	2	1	6	—
J	2 lbs hydrated lime	1 lb nitrate of soda, March 20th 1 lb nitrate of soda, April 20th 2 lbs nitrate of soda, June 1st	4	4	2	10	0.41	265	3	1	4	8	0.48
K	4 lbs hydrated lime	2 lbs hydrated lime, March 20th 2 lbs ammonium sulphate, April 20th 2 lbs ammonium sulphate, June 1st	4	3	2	9	0.51	343	2	3	3	8	0.45
L	8 lbs hydrated lime	8 lbs hydrated lime	1	0	4	5	—	193	1	0	5	6	—
Check	None	None	3	1	-	4	—	311	3	-	1	4	—

*A scale from 0, indicating no potash deficiency symptoms, to 5, indicating all leaves severely affected.

†1942—All treatments applied March 20th, except as noted.

‡1941—All treatments applied August 23rd.

were necrotic. It was assumed that the chlorotic and the necrotic pattern represent early and advanced stages of the same disorder. In setting up the experiment, six replications of 16 trees each were used. Three replications involved trees showing the chlorotic stage, and the other three, trees showing the necrotic stage. Each of the 12 fertilizer treatments was applied to one tree in each replication, or a total of six trees, three of them chlorotic and three necrotic. The arrangement was systematic, and every fourth tree was reserved as a check, so that there were four check trees in each replication.

The trees were closely watched during the season of 1942, and by August it was evident that the disorder had been corrected on those trees that received a heavy application of muriate of potash, or an application of nitrate of potash of 14–0–44 composition. On November 4th, the condition of the foliage on each tree in the experiment was scored, assigning ratings from 0 (complete absence of the potassium deficiency pattern), to 5 (all leaves on the tree affected). In addition, the total amount of new shoot growth from 10 terminal buds of the previous season, taken at random on each tree of the necrotic series, was measured. The data are presented in Table I.

Statistical analysis of the foliage scores by analysis of variance is not feasible due to the lack of homogeneity of the variances of the different treatments. Owing to the small number of trees in each treatment, it was felt that any statistical treatment other than analysis of variance would be of little value. Inspection of the data shows that individual trees showed symptoms of the deficiency in widely varying degrees. It may be noticed that the scores of the check trees ranged from 1 to 5. Although none of the check trees were free of the trouble, they showed extreme diversity in foliage condition under identical treatment. The average potassium content of their leaves was about 0.50 per cent. Although the reason is not known, it is apparent that it is much more difficult to correct the trouble in certain individual trees than in others. The deficiency symptoms were completely eliminated by treatment F, which was 5 pounds of muriate of potash per tree in 1942 following 3 pounds of muriate of potash in 1941, and by treatment G, which was 3 pounds of 14–0–44 nitrate of potash per tree in 1942 following 2 pounds of dolomite in 1941. In both of these treatments the potassium content of the leaves was raised to 0.80 per cent or higher. Most of the trees receiving treatment E, 2 pounds of muriate of potash each year, showed no symptoms of the deficiency, and the average potassium content of the leaves was 0.74 per cent; but the very stubborn cases apparently were not corrected by an application of potassium at this level.

The blades of the leaves of the trees that received additional nitrogen only in 1942 (treatments J and K) were distinctly darker green in color than those on other trees in the experiment. However, the symptoms of potassium deficiency, in either the chlorotic or necrotic series, was just as prevalent on these trees as on the checks. The potassium content of leaves on trees receiving these treatments averaged 0.46 per cent, which is about the same as the checks. It is also evident from the data for foliage scores and leaf potassium content, that treatment C (magnesium sulphate) was of no benefit whatever. In fact, this treatment may have aggravated the disorder. The use of dolomite and of hydrated lime gave varying results. On the whole, the condition of these trees seemed to be better than that of the checks. It might be expected that in these acid soils the application of calcium would render the potassium of the soil more available to the trees. However, no definite conclusions are justified either from the foliage scores or from the potassium content. Supplemental applications of phosphorus appeared to be of no benefit whatever.

A statistical analysis of the data on shoot growth in the necrotic series shows that the treatments produced highly significant effects. The value of F for treatments is 3.69, where an F of 2.74 is required to indicate significance on the .01 level. However, a more detailed examination of the data by means of standard errors calculated from the analysis of variance shows that only the treatment of 3 pounds of nitrate of potash significantly improved shoot growth. The improvement in foliage color and growth of these trees was very striking. They could be picked out by the casual observer from a considerable distance. Their average shoot growth per tree was 703 centimeters, 516 centimeters more than the average for all the check trees. This is a highly significant difference, giving a t value of 6.29, where a value of 2.75 is necessary for significance at the .01 level. Observations in the orchard give the impression that the trees receiving sulphate of ammonia and nitrate of soda had made somewhat better shoot growth than the check trees. However, it was found that the difference is not sufficient to warrant any conclusions. Likewise, the application of 5 pounds of muriate of potash (treatment F) failed to improve materially the shoot growth of the trees. Evidently, the trees require both nitrogen and potash in order to produce a significant growth response.

The results reported here corroborate the conclusion reached by Drosdoff and Painter that the leaf disorder is due to potassium deficiency. Extensive experiments are now in progress to determine the most economical and practical means of overcoming this trouble, and obtaining satisfactory growth and production by tung trees on these soils.

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Nitrogen Intake of Dormant Apple Trees at Low Temperature

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SEVERAL investigators (1, 6) have reported the absorption of nitrogen by apple tree roots during the winter months when the tree tops were dormant. In field experiments conducted in the Appalachian area, the writers found that the nitrogen content of roots of Delicious apple trees growing in a shale loam and receiving an application of 8 pounds of sodium nitrate after leaf fall (November 25) showed a 66 per cent increase from January 25 to March 17. With a similar set-up of York Imperial trees growing in a Hagerstown clay loam, and with a lower initial nitrogen content, the nitrogen increase in the roots during this same period was only 6 per cent.

In many fruit sections the temperature of the upper 18 inches of soil during the winter months fluctuates between 32 and 40 degrees F a large percentage of the time. It is probable that very little if any root growth takes place at these temperatures, even in a favorable rooting medium (2). However, information is lacking as to the effect of low temperature as well as the nature of the rooting medium on the activity of established roots. The present studies were undertaken in an attempt to obtain information pertaining to these phases of the problem.

Methods and 1939–40 Results

On March 15, 1939, 17 1-year-old Delicious trees were selected from the nursery row and potted in pure washed sand, using 3-gallon glazed earthenware crocks with a hole at the base to provide drainage. The trees were cut back within 1 inch of the graft union and only one bud was allowed to develop. Eight of the trees received a complete nutrient solution containing 100 parts per million of nitrate nitrogen during the 1939 growing season. The remaining nine trees were supplied with a nutrient solution containing only 10 parts per million of nitrogen. These trees were grown in the greenhouse till October 1. On this date they were exposed to outside temperatures, receiving only an occasional watering to keep the sand moist. On December 26, after the trees had been dormant for some time, they were returned to the greenhouse for further treatment. Individual root samples were taken by digging into the sand and removing one or more roots with a minimum of disturbance of remaining roots. Bark samples were obtained by removing small narrow strips of tissue. Ten trees (six high-nitrogen trees and four low-nitrogen trees) were placed in a specially designed temperature chamber (2) in which the roots and lower portion of the trunks were held at a temperature of 38 to 40 degrees F. The tops of these trees were exposed to the greenhouse temperature, which was held as near 45 degrees F as possible, but in a few instances on bright sunny days a maximum of 60 degrees F was reached. The remaining seven trees had both the roots and tops continued at greenhouse temperatures (45 to 60 degrees F). On December 27 treatments were applied as indicated in Table I.

RESULTS

All trees (Nos. 1, 2, 3, 7, 8, 11, 12, 15) Table I, receiving the higher nitrogen nutrient during the growing season had a significantly higher organic nitrogen content of both bark and roots on December 26, just before the beginning of the dormant treatments. The data in Table I show that in every case where nitrate nitrogen was added to the nutrient solution there was a gradual and consistent increase in root nitrogen throughout the dormant period. It will be seen (Table I) that the roots of the low-nitrogen trees showed a greater increase in nitrogen than the roots of the high-nitrogen trees. The lower rate of increase in the latter group was doubtless due to the fact that these roots were nearer to a condition of nitrogen equilibrium at the beginning of the experiment on December 27. Roots of control trees receiving a minus nitrogen nutrient showed no consistent trend in nitrogen, varying in per cent change from −0.11 to +0.19.

TABLE I—EFFECT OF ROOT TEMPERATURE ON NITROGEN INTAKE OF DORMANT DELICIOUS APPLE TREES

Tree Number	Treatment Dec 27, 1939 to Mar 9, 1940		Total Nitrogen Content of Roots 5 Mm or Less in Diameter (Per Cent Dry Weight)				Nitrogen Change in Roots Dec 16, 1939 to Mar 9, 1940 (Per Cent Dry Weight)	Total Nitrogen Content of Bark (Per Cent Dry Weight)	
	Root Temperature (Degrees F)	Nutrient Supplied	Dec 26, 1939	Jan 20, 1940	Feb 17, 1940	Mar 9, 1940		Dec 26, 1939	Mar 9, 1940
1	38–40	Complete*	1.27	1.62	1.80	1.88	+0.61	2.16	2.34
2	38–40	Complete*	1.11	1.32	1.61	2.03	+0.92	1.54	1.47
3	38–40	Complete*	1.09	1.23	1.54	1.89	+0.80	1.50	1.57
4	38–40	Complete*	0.84	1.11	1.33	1.94	+1.10	0.92	0.94
5	38–40	Complete*	0.62	0.92	1.49	1.64	+1.02	0.85	0.82
6	38–40	Complete*	0.49	0.88	1.38	1.56	+1.07	0.88	0.88
7	38–40	Water only	1.28	1.27	1.30	1.37	+0.09	1.78	1.91
8	38–40	Water only	1.18	1.22	1.24	1.28	+0.10	1.26	1.29
9	38–40	Water only	0.59	0.48	0.55	0.48	−0.11	0.90	0.86
10	38–40	Water only	0.57	0.51	0.48	0.48	−0.09	1.02	0.83
11	45–60	Complete*	1.15	1.36	1.46	1.99	+0.84	1.20	1.32
12	45–60	Complete*	1.00	1.19	1.25	1.49	+0.49	1.10	1.40
13	45–60	Complete*	0.54	0.64	1.49	1.58	+1.04	0.95	0.89
14	45–60	Complete*	0.46	1.02	1.44	1.56	+1.10	0.89	0.92
15	45–60	Water only	1.01	1.03	0.95	1.20	+0.19	1.22	1.34
16	45–60	Water only	0.59	0.58	0.52	0.58	−0.01	1.09	0.95
17	45–60	Water only	0.44	0.54	0.43	0.44	0.00	0.88	0.83

*A complete nutrient solution containing 117 parts per million nitrate nitrogen supplied twice monthly.

The changes in nitrogen content in the bark, presented in Table I, indicate that with root temperatures of 38 to 40 degrees F there was little if any nitrogen translocation to the top. This substantiates earlier results (2). With root temperatures of 45 to 60 degrees F, however, the present results show little or no nitrogen translocation to the top, in contrast to the earlier results, which indicated upward movement of nitrogen at root temperatures of 45 to 60 degrees F, with daily maximum temperatures of 65 degrees F during the March 15 to 20 period.

1941–42 EXPERIMENT

Material and Methods:—A new set of Delicious trees was potted in the spring of 1940, using as rooting media a loamy sand, a clay loam, with moisture equivalents of 7.9 and 21.0 per cent respectively, and Haydite, a rather inert burnt shale clay material. The Haydite trees received a low-nitrogen nutrient solution during the growing season; the soil-grown trees received no applied nutrient during this interval. On January 2 differential treatment was begun as indicated in Table II. All of the trees growing in soil were placed in the temperature chamber, which was adjusted to give a root temperature of 32 to 33 degrees F. The tops of these trees, as well as the tops and roots of the Haydite trees, were subjected to the greenhouse temperatures, which fluctuated between 45 and 60 degrees F.

Results:—While the number of trees for any one treatment is limited, nevertheless the data in Table II clearly indicate a significant rate of nitrogen absorption by the roots of these trees in all three rooting media when supplied with either ammonium or nitrate nitrogen at both the high and low root temperatures. Better aeration in the lighter-textured soil may have been responsible for the greater rate of nitrogen intake of tree roots in the sandy soil (4). This increase in the nitrogen content of the roots in the sandy loam soil was more than double that of roots in the clay loam soil with the ammonium sulfate treatment, and just slightly less than that amount in the case of the sodium nitrate treatment. The trees growing in Haydite at the higher root temperature showed generally a greater increase in root nitrogen, with practically no difference between the ammonium and nitrate nitrogen treatments. This higher rate of absorption cannot be definitely attributed to a temperature effect, since the ultimate nitrogen level in the roots of these trees was no higher than in roots of trees in the sandy soil held at a lower temperature. Here again the higher rate of nitrogen absorption by the roots of the Haydite trees could probably be accounted for by the fact that these roots were at a lower level of nitrogen at the beginning of the experiment.

Analysis of bark and wood (Table II) indicated that little if any of the absorbed nitrogen was translocated during dormancy. However, the slightly increased nitrogen content in the bark of the trees in soil receiving nitrate nitrogen suggests the possibility that some translocation did take place in trees receiving this treatment. This may partially explain the seemingly lower rate of nitrogen increase in the roots of these trees.

DISCUSSION

Under the conditions of the experiments herein reported, it is evident that appreciable nitrogen both in the nitrate and ammonium form was absorbed and changed to organic form in roots of dormant apple trees subjected to temperatures as low as 32 to 33 degrees F. In a fruit region such as the Appalachian area, which normally has a rather mild winter, even the top few inches of surface soil are seldom frozen for any great length of time. Results of these studies indicate that lack of nitrogen absorption under such conditions is likely due to factors other than soil temperature. In the case of the nitrogen experiment on York Imperial apples mentioned previously, the possibility is suggested that lack of adequate oxygen supply was largely responsi-

TABLE II—RELATIONSHIP OF ROOT TEMPERATURE, ROOTING MEDIUM, AND FORM OF NITROGEN TO NITROGEN INTAKE OF DORMANT DELICIOUS APPLE TREES (1942)

Tree Number	Rooting Medium	Treatment Jan 2 to Mar 16		Total Nitrogen Content of Roots 5 Mm or Less Diameter (Per Cent Dry Weight)		Nitrogen Change in Roots Jan 2 to Mar 16 (Per Cent Dry Weight)	Total Nitrogen Content of Bark (Per Cent Dry Weight)*		Total Nitrogen Content of Wood (Per Cent Dry Weight)*	
		Root Temperature (Degrees F)	Source of Nitrogen †	Jan 2	Mar 16		Jan 2	Mar 16	Jan 2	Mar 16
1	Sandy loam	32–33	Ammonium sulfate	0.64	1.17	+0.53	1.07	1.03	0.37	0.32
2	Sandy loam	32–33	Ammonium sulfate	0.72	1.20	+0.48				
3	Clay loam	32–33	Ammonium sulfate	0.52	0.66	+0.14	1.03	0.95	0.33	0.28
4	Clay loam	32–33	Ammonium sulfate	0.67	0.90	+0.23				
5	Sandy loam	32–33	Sodium nitrate	0.70	1.07	+0.37	1.06	1.21	0.36	0.38
6	Sandy loam	32–33	Sodium nitrate	0.78	1.09	+0.31				
7	Clay loam	32–33	Sodium nitrate	0.51	0.66	+0.15	1.04	1.11	0.34	0.32
8	Clay loam	32–33	Sodium nitrate	0.60	0.74	+0.14				
9	Haydite	45–60	Ammonium sulfate	0.43	0.87	+0.44	0.80	0.82	—	—
10	Haydite	45–60	Ammonium sulfate	0.49	0.97	+0.48				
11	Haydite	45–60	Ammonium sulfate	0.58	1.05	+0.47				
12	Haydite	45–60	Sodium nitrate	0.44	0.83	+0.39	0.82	0.83	—	—
13	Haydite	45–60	Sodium nitrate	0.55	1.09	+0.54				
14	Haydite	45–60	Sodium nitrate	0.58	1.07	+0.49				
15	Haydite	45–60	Water only	0.45	0.42	−0.03	0.82	0.87	—	—
16	Haydite	45–60	Water only	0.54	0.49	−0.05				
17	Haydite	45–60	Water only	0.46	0.46	0.00				

*Composite sample from all trees in a given treatment.

†Trees in soil saturated and allowed to drain prior to placement in temperature chamber. Solution applied contained 117 parts per million of nitrogen. Trees in Haydite received solution containing 117 parts per million nitrogen twice monthly.

ble for the inactivity of the roots in absorbing nitrogen during the winter months.

The data presented indicate that there is little if any nitrogen translocated from the roots when the tree top is dormant. Also the rate of nitrogen absorption was reduced when the initial nitrogen content of the roots was high as compared to the rate of intake when the nitrogen content was low. These results would indicate that there is a limit to the amount of nitrogen that would be absorbed and held by the roots during the dormant season, though the intake might be almost sufficient to carry the trees through a season's growth, based on the results of Magness and Regeimbal (5). Since water is not withdrawn from the soil by vegetation to any extent during the dormant season, accumulated rainfall causes a downward leaching of soluble nitrogen (3). This leaching is most rapid in open-textured soils, in which these results indicate that nitrogen uptake by roots is also most rapid. Thus late fall or early winter applications of soluble nitrogen may result in considerable loss of nitrogen by leaching in areas of heavy winter precipitation. The nitrogen that does enter the roots, however, will be readily translocated and available for utilization when growth begins the following spring.

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Control of Manganese Deficiency in a Commercial Tung Orchard[1]

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A PHYSIOLOGICAL disorder of tung (*Aleurites fordii Hemsl.*) called frenching, which responds to soil and foliage treatments with manganese sulfate, was reported from Florida by Reuther and Dickey (3) in 1937. It was estimated that from 5 to 10 per cent of the trees in the orchards surveyed showed frenching symptoms in some degree. In subsequent years this disorder has reappeared in those tung orchards in which it had previously been noted (3) and has also been observed in other plantings. The prevalence of symptoms varies widely between orchards and between different areas in the same orchard. Also, it has been noted that symptoms are most acute early in the season and, in certain instances, tend to clear up without treatment as the season progresses.

Reuther and Burrows (4) found that there is a reduction in photosynthetic activity of frenched tung leaves but that this effect is not very pronounced. They suggest that frenched tung trees tend to produce small leaves and that the reduction in total leaf surface is possibly of more importance than the reduction in leaf efficiency noted.

Very little data are available on the rates of soil application of manganese sulfate needed in commercial tung orchards in Florida to correct manganese deficiency. The purpose of the experiments here reported was to obtain information relative to the application of manganese sulfate to the soil as this is the most desirable method of treatment from the tung grower's standpoint.

EXPERIMENTS

The experimental work was conducted in 1941 and 1942 in a tung orchard near Reddick, Florida. This orchard is on an Arredonda loamy fine sand and for several years has received no commercial fertilizer and only small amounts of barnyard manure at irregular intervals. Zinc sulfate has been applied for the control of bronzing (zinc deficiency). The general condition of growth and vigor of the trees was fair; however, acute symptoms of frenching were evident throughout the orchard at the time the experiments were begun. The trees for the tests were selected primarily for uniformity in size, crop, and degree of frenching. They were 13 or 14 years of age when treatments were first applied.

At the time of treatment in August, 1941, all trees used in these experiments were examined and a record was made of the relative severity of manganese-deficiency symptoms. Further examinations were made twice during the 1942 season. For convenience in presenting results these records were converted into numerical values for each tree. Manganese deficiency was scored as follows: 0 indicated no frenching, 25 indicated slight frenching, and 100 very severe frenching with all of the foliage affected, while 50 to 75 indicated intermediate conditions. The values for the individual trees were then added and the sum divided by the number of trees in a treatment. In interpreting these figures it can be seen that a treatment group with a frenching record of 100 would be very severely affected, while one with a score of zero would show no symptoms.

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[1] The authors wish to acknowledge the help of Dr. George F. Potter in the statistical analysis.

MANGANESE TREATMENTS

The initial manganese treatments, made on August 2, 1941, in 15 replications of four trees each, were as follows: 1, 2, and 4 pounds, respectively, of 65 per cent manganese sulfate per tree and an untreated check. At the same time, all trees received ½ pound of zinc sulfate. The manganese treatments were repeated on March 17, 1942, and in addition, all trees received 5 pounds of a 5–7–5 fertilizer and ½ pound of zinc sulfate. All materials used were applied broadcast under the spread of the tree branches. Data showing the results obtained are given in Table I. These data show that frenching was materially reduced by the application of manganese and that the reduction was directly proportional to the amount applied. Analysis of the data shows that all of the differences observed have high statistical significance except the difference between 2 and 4 pounds of manganese sulfate which is supported by odds of about 19: 1. The foliage scores correlate very well with the manganese content of the foliage which increases directly with the amount of manganese sulfate applied, from an average of 25 parts per million of manganese in the leaves from the check trees to an average of 322 parts per million in those from the 4 pound treatment. From the data obtained under the conditions of this experiment, it would appear that 2 pounds of 65 per cent manganese sulfate is a satisfactory commercial application to correct manganese-deficiency symptoms in severely affected trees.

TABLE I—EFFECT OF SOIL APPLICATIONS OF MANGANESE SULFATE IN CORRECTING FRENCHING AND INCREASING THE MANGANESE CONTENT OF TUNG LEAVES (REDDICK, FLORIDA, 1941–42)

Treatments Applied on Aug 2, 1941 and Mar 17, 1942	Average Degree of Frenching on Different Dates			Manganese Content of Foliage (Dry Basis,† Parts Per Million)
	Aug 2, 1941 (Score)*	May 29, 1942 (Score)*	Aug 10, 1942 (Score)*	
None (check)	76.6	81.7	60.0	25
1 pound manganese sulfate	80.0	52.7	22.7	43
2 pounds manganese sulfate	78.3	26.7	6.3	100
4 pounds manganese sulfate	83.3	15.6	0.7	322

*On a scale from 0, which indicates no frenching, to 100, which indicates very severe frenching of all foliage.

†Average of four replications. Samples collected in August 1942.

MANGANESE AND MAGNESIUM TREATMENTS

Magnesium deficiency, which has chlorosis as one of its primary symptoms, is common in citrus trees in Florida, particularly on light sandy soils. This deficiency often occurs simultaneously with manganese and other deficiencies on citrus (1) and for complete response it would be necessary to treat affected trees with all elements that are deficient.

To determine whether the disorder present in this tung orchard was in any way connected with a deficiency of magnesium, a second experiment was set up which comprised eight replications of three trees each selected on the same basis as described previously. Treatments were first applied on August 2, 1941, and consisted of: (a) 2 pounds per tree of 65 per cent manganese sulfate; (b) 2 pounds of 65 per cent manganese sulfate and 2 pounds of 90 to 92 per cent magnesium sulfate per tree; and (c) untreated check. In addition, all trees were given ½ pound of zinc sulfate. These treatments were repeated on March 17, 1942, and at the same time all trees received 5 pounds of a 5–7–5 fertilizer. The data obtained are given in Table II.

TABLE II—EFFECT OF SOIL APPLICATIONS OF MANGANESE SULFATE WITH AND WITHOUT MAGNESIUM SULFATE IN CORRECTING FRENCHING OF TUNG LEAVES (REDDICK, FLORIDA, 1941–42)

Treatments Applied on Aug 2, 1941 and Mar 17, 1942	Average Degree of Frenching on Different Dates		
	Aug 2, 1941 (Score)*	May 29, 1942 (Score)*	Aug 10, 1942 (Score)*
None (check)	78.1	78.1	68.8
2 pounds manganese sulfate	75.0	17.5	6.3
2 pounds manganese sulfate plus 2 pounds magnesium sulfate	81.2	15.0	6.3

*On a scale from 0, which indicates no frenching, to 100, which indicates very severe frenching of all foliage.

A statistical analysis of the data by the analysis of variance shows that there is no significant difference between the manganese and manganese-magnesium treatments; but each of these treatments gives a highly significant difference when compared with the check. Thus it is apparent that the manganese treatments have greatly reduced frenching and that there is no additional beneficial effect from the magnesium.

MANGANESE AND AMMONIUM SULFATE TREATMENTS

Some tung growers have believed that ammonium sulfate was beneficial in reducing frenching symptoms. There has been no previous experimental work to confirm this belief. To obtain information relative to this point a third experiment was started on March 17, 1942. The trees were selected on the same basis as given previously. Fertilizer application per tree was as follows: (a) 3 pounds of ammonium sulfate; (b) 2 pounds of 65 per cent manganese sulfate; (c) 2 pounds of 65 per cent manganese sulfate and 3 pounds of ammonium sulfate; and (d) untreated check. Each set of treatments was replicated eight times. All trees received, in addition, 1 pound of 18 per cent superphosphate, 1 pound of muriate of potash and ½ pound of zinc sulfate. The data are given in Table III.

The data show that the ammonium sulfate treatment increased the manganese content of the leaves from an average of 30 to 51 parts per million. This difference has high statistical significance. The foliage scores indicate some improvement from the use of ammonium sulfate

TABLE III—EFFECT OF SOIL APPLICATIONS OF MANGANESE SULFATE AND AMMONIUM SULFATE SEPARATELY AND TOGETHER, IN CORRECTING FRENCHING AND INCREASING THE MANGANESE CONTENT OF TUNG LEAVES (REDDICK, FLORIDA, 1942)

Treatments Applied on Mar 17, 1942	Average Degree of Frenching on Different Dates			Manganese Content of Foliage (Dry Basis)† (Parts Per Million)
	Aug 2, 1941 (Score)*	May 29, 1942 (Score)*	Aug 10, 1942 (Score)*	
None (check)	75.0	71.9	48.8	30
2 pounds manganese sulfate	71.9	33.8	11.3	67
3 pounds ammonium sulfate	65.6	75.0	29.4	51
2 pounds manganese sulfate plus 3 pounds ammonium sulfate	62.5	33.1	5.6	122

*On a scale from 0, which indicates no frenching, to 100, which indicates very severe frenching of all foliage.

†Average of four replications. Samples collected in August 1942.

but statistical analysis did not show the difference to be significant. In view of the increased manganese in the leaves, however, it is believed that there is an actual improvement due to the use of ammonium sulfate. This supports the observations reported by certain tung growers.

Two pounds of manganese sulfate effected a highly significant improvement over the check both in foliage score and in manganese content of the leaves. The relation of the manganese sulfate plus ammonium sulfate treatment to the manganese sulfate alone is similar to the relation of the ammonium sulfate treatment to the check. In other words the addition of ammonium sulfate to the manganese sulfate effected a highly significant increase in the manganese content of the leaves but did not improve to a statistically significant degree the foliage score over manganese sulfate alone. The difference between the effect of manganese sulfate as compared with ammonium sulfate was not statistically significant both in regard to foliage score and manganese content of the leaves.

The beneficial effect of ammonium sulfate in increasing the manganese content of the leaves and improving the foliage score probably involves several factors. It is possible that the trees were not receiving adequate nitrogen and the addition of ammonium sulfate probably stimulated the vegetative growth and the absorbing capacity of the root system for manganese. Another possibility is that the ammonium sulfate has rendered more manganese available in the soil as has been indicated by other investigators (2, 5).

SUMMARY

In commercial orchard practice, 2 pounds of 65 per cent manganese sulfate appears to be a satisfactory soil application for correcting severe manganese deficiencies in mature tung trees on Arredonda loamy fine sand soil. The addition of magnesium sulfate did not increase the effectiveness of the manganese sulfate treatment. Ammonium sulfate either alone or in combination with the manganese sulfate is beneficial.

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Copper Deficiency of Tung Trees[1]

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IN the late summer of 1941 an abnormal foliage condition, which proved to be due to a copper deficiency, was observed in a few trees in a large mature tung orchard near Morriston, Florida. In the late spring and summer of 1942 it was found in several tung orchards in the Gainesville area. A newly planted orchard near Alachua, Florida, and a bearing orchard near Morriston, Florida, were severely affected by the disorder.

The symptom most characteristic of the deficiency is a "cupping" of the terminal leaves which are usually abnormally small and show an interveinal chlorosis. A tip and marginal burn of the terminal leaves generally accompanies the cupping and chlorosis. As the disorder increases in severity the necrotic areas enlarge rapidly until finally abscission of the terminal leaves occurs. With the defoliation of the upper part of the shoot, the growing point becomes affected and finally dies; also certain of the affected shoots may die back in varying degree (Fig. 1). Shoot growth from axillary buds is stimulated. At this stage the older leaves are characterized by an interveinal chlorosis and ragged necrotic margins. The chlorosis and necrosis of the leaves, defoliation and "dieback" of terminal shoots and stunted growth of the trees are symptoms which are, in general, characteristic of copper deficiency in other orchard trees although they differ in some details (1, 2, 3, 5).

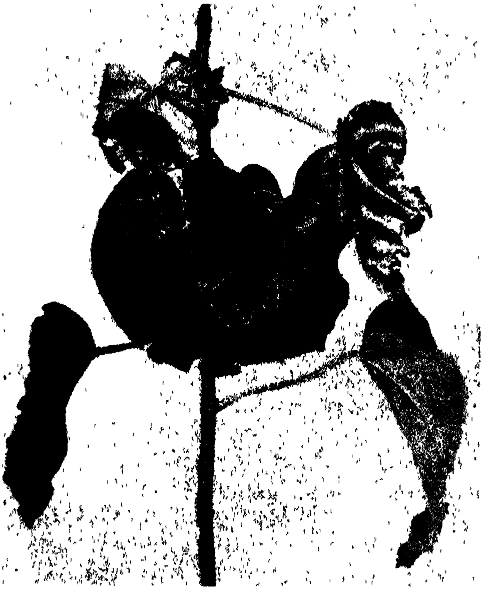

FIG. 1. Branch from tung tree showing acute symptoms of copper deficiency-cupping, chlorosis, defoliation, ragged leaves, and dead terminal bud.

EXPERIMENTS

When the abnormal foliage condition was first observed on a few trees in an orchard near Morriston, Florida, in the late summer of 1941 some foliage dips were tried with solutions of ferrous sulfate, manganese sulfate, borax and copper sulfate. It proved to be

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[1] The authors wish to thank Mr. G. T. Sims for making the copper determinations.

too late in the season, however, for any of the treatments to be effective.

By the latter part of May 1942, a boron or copper deficiency was suspected on the basis of observable symptoms. A series of treatments using borax and copper sulfate were tried on affected tung trees in a 2-year-old orchard near Alachua, Florida. About a month later it was found that practically all of the treated and untreated trees had recovered from the disorder and were making normal growth. Therefore, no conclusions could be drawn. Meanwhile a large block of 1-year-old trees in the same orchard were showing severe symptoms and it was decided to initiate some treatments in this block.

A preliminary trial[2] with a mixture of 10 micro elements applied in solution to the soil at the base of the tree had effected partial recovery in a week's time and this lead was followed in setting up further treatments. The 10 elements were divided into three groups. Each group was made up into a test solution and a fourth solution comprised all 10 compounds. A list of the compounds and the amounts used are given in Table I. The solutions were applied on June 24 to the soil at the base of the tree at the rate of about 350 milliliters per tree. This amount of solution contained 5 grams each of boric acid, copper sulfate, or zinc sulfate, or 1.3 grams of any of the other compounds, these last being considered to be more toxic. There were three trees in each treatment and three replications. These 1-year-old trees had received ½ pound of 5–8–6 fertilizer in the spring. By July 8 practically all of the trees that had received either the complete solution or the solution of copper, cobalt, and lead had recovered and were making normal growth. The other solutions had no beneficial effect.

TABLE I—LIST OF TREATMENTS USED IN PRELIMINARY TRIALS TO CORRECT CUPPING AND CHLOROSIS IN YOUNG TUNG TREES (ALACHUA, FLORIDA, JUNE, 1942)

Treatment	Compounds	Amount Used Per Tree* (Grams)
1	Boric acid	5.0
2	Cupric sulfate	5.0
	Cobaltous sulfate	1.3
	Lead acetate	1.3
3	Zinc sulfate	5.0
	Molybdic acid	1.3
	Bismuth subnitrate	1.3
	Uranium acetate	1.3
	Lithium nitrate	1.3
	Thorium nitrate	1.3
4	All of above	5.0 grams of cupric sulfate, cobaltous sulfate, and zinc sulfate, 1.3 grams of the other compounds

*Applied in solution in 350 milliliters of water.

On the basis of these preliminary trials the list of possible elements effecting recovery was narrowed down to three. Another test was begun, therefore, in an adjacent block of affected 1-year-old trees and the same amounts of copper sulfate, cobaltous sulfate, and lead acetate as those shown in Table I were applied separately in solution. Inasmuch as certain of the symptoms were somewhat similar to zinc deficiency, zinc sulfate was also included in the experiment although the first test had given a negative response. Three trees were used for each treatment and there were three replications. The solutions were applied to the soil at the base of the tree on July 8 and 1 week later the copper treated trees were showing definite recovery, whereas the trees in the other treatments were unaffected. Untreated trees in the experiment showed no signs of recovery. On August 5 the trees were scored and it was found that seven of the nine copper treated trees had completely recovered and were making normal growth (Fig. 2). The remaining two trees had also largely recovered. On analysis the recovery due to copper was found to have high statistical significance whereas none of the other treatments showed any significant improvement over the checks. On the basis of these results the owners of the orchard treated several thousand affected young trees with a similar copper sulfate solution, practically all of which recovered and were growing normally by the end of the season.

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[2] This work was done by Mr. Joseph Hamilton of the United States Field Laboratory for Tung Investigations, Gainesville, Florida, in an attempt to correct the trouble on affected trees in a pruning experiment.

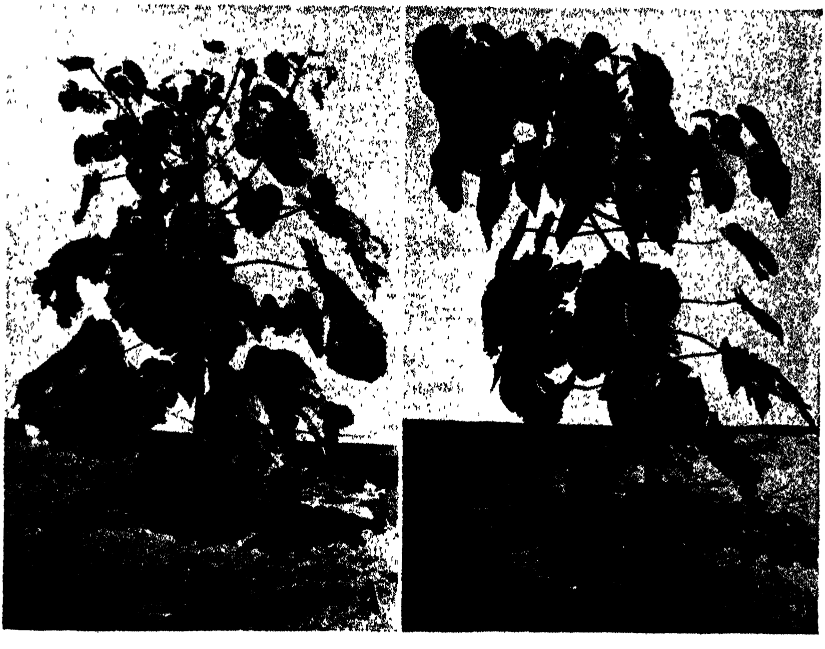

FIG. 2. A, One-year-old tung tree showing acute symptoms of copper deficiency (cupping, defoliation and ragged leaves). B, One-year-old tung tree which had symptoms similar to those of (A) at time of treatment on July 8, 1942 with 1/6 ounce of copper sulfate in 350 milliliters of water applied to soil at base of tree. The copper treatment has effected complete control of copper deficiency, while (A) continues to show acute symptoms. Photographs taken August 5, 1942.

Analyses of leaf samples collected from the experimental plots on August 10 showed a copper content of about 3 parts per million in the untreated trees and about 4 parts per million in the copper treated trees (Table II). It is shown that the soil application, which was only about 5 grams per tree, increased the copper content in the leaves from 3.1 to 4.0 parts per million. Apparently the amount of copper necessary to effect recovery is exceedingly small. This corresponds to the experience of Piper (4) who, working with small grains, found that increased absorption of copper by plants that recovered as a result of soil applications was surprisingly small.

TABLE II—Copper Content of Leaves from Healthy and Affected Tung Trees

Location of Orchard	Age of Trees	Treatment	Condition of Trees	Average Copper Content of Leaves (Dry Basis) (P P M)
Alachua, Florida	One year	None	Affected	3.1
Alachua, Florida	One year	5 grams copper sulfate per tree	Normal, but affected before treatment	4.0
Morriston, Florida	Mature	None	Affected	2.6
Morriston, Florida	Mature	None	Normal. Adjacent to affected trees	4.1
Morriston, Florida	Mature	None	Normal. No affected trees adjacent	5.7

Leaf samples were collected also from affected trees in the mature orchard near Morriston, Florida, and from trees in an adjacent normal block. Data on the copper content in these samples are given in Table II. The difference in copper content is clear cut. There was an average of 2.6 parts per million of copper in leaves from affected trees and 5.7 parts per million in leaves from normal trees in an adjacent healthy block. Leaves from normal trees in the affected area contained 4.1 parts per million of copper.

As further evidence about 20 one-year-old trees located on the University of Florida Agricultural Experiment Station Minor Farm, all of which showed distinct symptoms of copper deficiency, were sprayed with a copper sulfate solution, 1 per cent on certain plots and 2 per cent on others. About the same number of affected trees were left unsprayed. Less than 1 month later it was found that almost all of the sprayed trees had completely recovered, whereas there was no significant improvement in the untreated trees which were still showing severe symptoms.

Development and Extent of Deficiency

It appears that copper deficiency symptoms in tung trees may develop any time during the growing season. In 1941 they were first observed in late summer. In 1942 they were found widespread in the spring. In an orchard planted near Alachua, Florida in 1941, trees that showed the symptoms in May 1942, were growing normally 1 month later without having received any treatment. On the other hand trees in the same block that appeared normal in May were showing severe symptoms in August. Similar observations were made in other orchards in Alachua and Levy Counties.

The disorder has been observed in a number of orchards in north central Florida and in some cases a large acreage has been affected. Several hundred acres of young trees were affected in the orchard near Alachua, Florida. In a mature bearing orchard near Morriston, Florida, it was estimated that over 100 acres of trees were showing the symptoms in varying degrees. Several orchards in the vicinity of Gainesville, Florida, were observed to have some affected trees. It is interesting to note, however, that in two of the largest tung orchards near Gainesville, Florida, the symptoms were not observed. In these orchards copper sulfate has been applied regularly in the fertilizer mixture.

PRACTICAL RECOMMENDATIONS

The experiments have shown that about 5 grams or 1/6 ounce of copper sulfate in 350 milliliters of water applied to the soil at the base of an affected 1-year-old tung tree was sufficient in 1942 to effect recovery and maintain normal growth from the middle of the summer to the end of the growing season. However, there were some trees which did not recover completely with this treatment. In commercial practice where young trees are showing symptoms of copper deficiency and quick recovery is desired, it is believed that 1 pint of a solution containing 1 pound of copper sulfate dissolved in 10 gallons of water applied to the soil at the base of the tree will be satisfactory. In an area where copper deficiency is prevalent it would be desirable to apply dry copper sulfate to the soil in the spring along with the zinc sulfate which is commonly used in all the orchards in the area where copper deficiency has been observed. The amount of dry copper sulfate required has not been determined experimentally, but it is believed that 1 or 2 ounces would suffice for trees up to 2 years of age.

Experiments are now under way in a copper deficient area near Morriston, Florida, to determine the levels of copper sulfate that need to be applied to the soil in solution or as the dry salt to effect recovery of mature trees. As much as 60 pounds of copper sulfate per acre is sometimes applied in Florida citrus orchards. Pending further information the use of about ¼ to ½ pound of copper sulfate per tree can safely be recommended for mature orchards, the material being distributed under the spread of the branches.

SUMMARY

A cupping and chlorosis of leaves and defoliation and dieback of shoots in tung were found to be due to a copper deficiency. Recovery and normal growth of 1-year-old trees were effected by applying 1/6 ounce of copper sulfate in solution to the soil at the base of the tree or by spraying with copper sulfate solution.

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Magnesium Deficiency in Massachusetts Apple Orchards[1]

By LAWRENCE SOUTHWICK, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

A DISTINCT type of leaf scorch was noted on individual McIntosh trees in two Experiment Station apple orchards at Amherst in September, 1939. At this time, also, it was observed that these trees were beset with excessive preharvest drop of fruit. The Thornton quick test for potassium showed a high level of this element in the leaves from affected trees (*7*). In August, 1941, the same deficiency symptoms became prevalent in other orchards and particularly in a 3-year-old clonal-stock orchard at Amherst. The symptoms suggested magnesium deficiency and limited chemical analyses of leaves tended to support this hypothesis.

It is the purpose of this paper to present evidence of magnesium deficiency in Massachusetts apple orchards and especially to show the relationship between visible foliage symptoms and the relative amounts of magnesium and other elements in leaf tissue.

MATERIALS AND METHODS

The investigational work was largely confined to chemical analyses[2] of leaf tissue from small apple trees growing in differentially fertilized soil in pots in the greenhouse and from orchard trees growing in experimental orchards showing variable incidence of deficiency symptoms. The leaf samples were dried and all analytical results were computed on the dry weight basis. Leaves for analysis were taken from trees on the basis of the relative severity of the deficiency symptoms present at the time of collection. This made it possible to correlate leaf condition with any one or any combination of its determined constituents. Approximately 125 leaves were taken from current shoot growths for each sample. Tip and basal leaves and those visibly scorched were not included.

SYMPTOMS OF MAGNESIUM DEFICIENCY

The symptoms of magnesium deficiency on apple trees are supposed to be rather clear cut and in most cases easily identified. This proved to be the case with both pot-grown and orchard trees. Until the latter part of July or the first two weeks of August, the trees appeared quite normal. Bloom, shoot growth, leaf size and color, and density of foliage gave no indication of a deficiency. Then, rather suddenly, in most cases, leaf scorch appeared as edge burn or more commonly as intervenal necrosis. Often, with some varieties, this burning was preceded or accompanied by yellow banding and mottling. In the greenhouse in winter, symptoms appeared about 2 months after growth started.

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[1] Contribution No. 462 from the Massachusetts Agricultural Experiment Station.

[2] These analyses were made under the direction of Mr. P. H. Smith of the Fertilizer Control Service.

Typical leaf symptoms are seen in Figs. 1 to 4. Usually, symptoms appeared first on older leaves near the base of the current year's shoot growth and progressed upward as the season advanced. Affected leaves often dropped off, leaving conspicuous bare stretches of wood. On bearing trees the preharvest drop of fruit was increased markedly. The various symptoms were essentially the same as those described for magnesium deficiency by Wallace (9) in England, Hill (3), and Davis and Hill (1) in Canada.

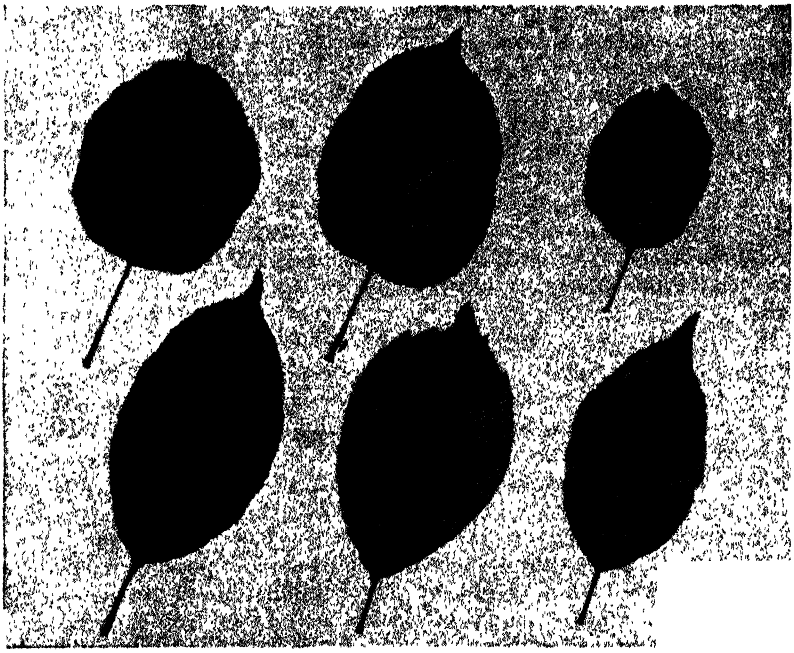

FIG. 1. Typical symptoms of magnesium deficiency on leaves of Malling IV (top) and Malling V (bottom) trees growing in the greenhouse (1942). From left to right, leaves are normal, distinctly scorched, and very severely burned.

BLOCK B — DESCRIPTION

The soil is a Wethersfield fine sandy loam. It had been cropped intensively and was in a "run-down" condition prior to the setting of an orchard in 1915. At this time wet areas were tile-drained. The land slopes gently to the west and has suffered considerable erosion. By 1932, the apple trees showed evidences of a potassium shortage (5) and subsequently responded to potash fertilization (6). In 1937 this orchard was pulled out and a complete fertilizer and cover-crop program was initiated to build up the soil. The present clonal-stock orchard was set in 1939 and the trees have been heavily mulched to date. In 1940 and 1941 each tree was given a liberal application of nitrate of soda and muriate of potash. The pH of the soil is around 5.0.

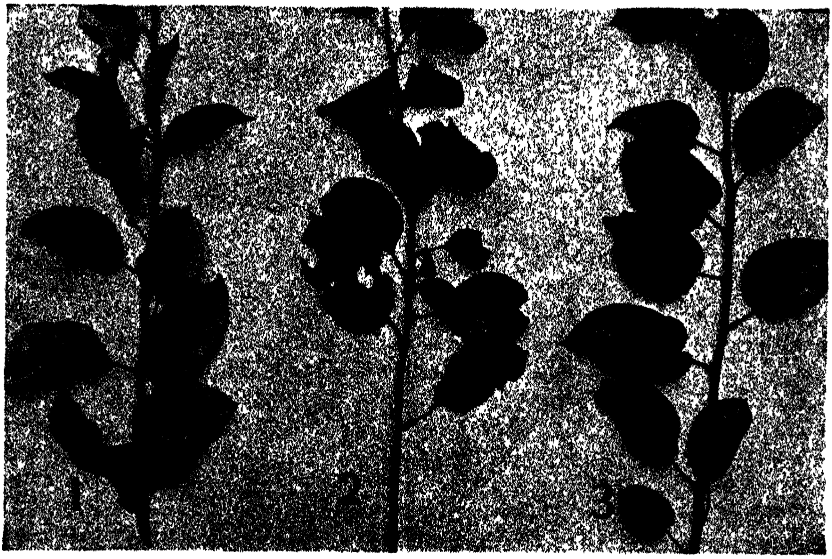

FIG. 2. Typical magnesium deficiency symptoms on current shoot growths in late August, 1942. From left to right, Golden Delicious (1), Gravenstein (2), McIntosh (3). Note the chlorosis and mottling in (1) and their absence in (3).

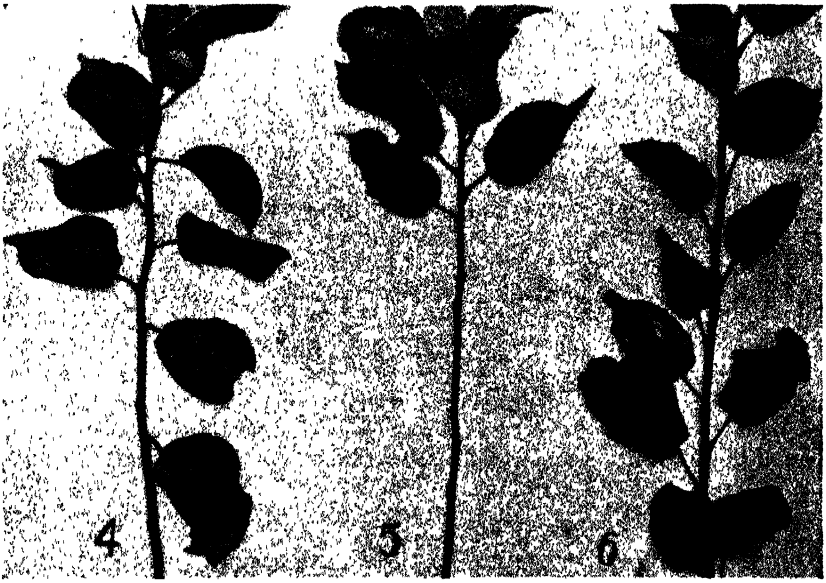

FIG. 3. Same as Fig. 2 except that varieties from left to right are: Baldwin (4), Wagener (5), Duchess (6). Note that leaves have fallen off prematurely especially in (5).

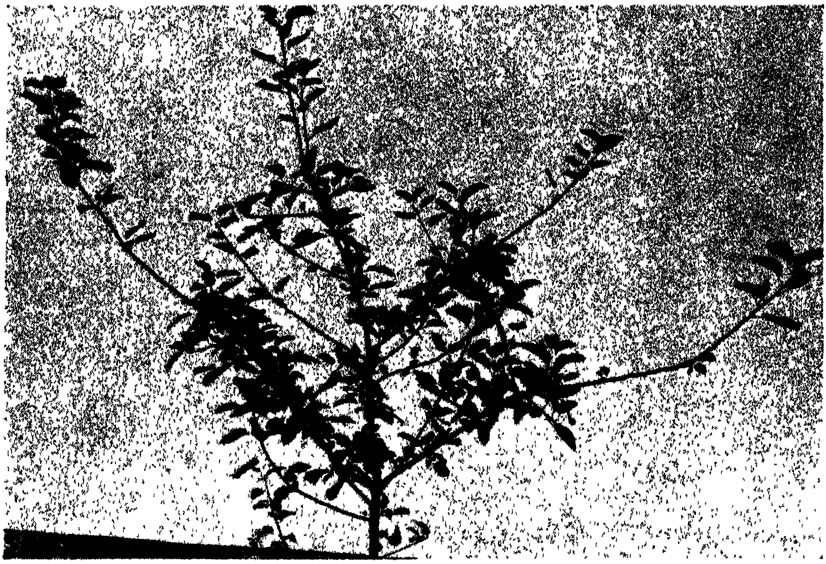

FIG. 4. Young Baldwin tree showing severe magnesium deficiency symptoms. The leaves are scorched and rolled. Bare stretches of wood indicate considerable premature leaf fall.

GREENHOUSE EXPERIMENT

In October, 1941, soil was collected from Block B in areas where the young apple trees were showing serious deficiency symptoms. Later the soil was screened and on February 3, 1942, fertilizer additions were thoroughly mixed into the soil for each pot series. Two- and three-gallon earthenware crocks were used. A Malling IV or V 1-year rootstock was planted in each crock, each treatment including four crocks, two with Malling IV and two with Malling V. Watering was through soil tubes, and moisture was maintained at as near optimum level as possible. The crocks had no drainage holes. Around the middle of April, deficiency symptoms began to appear on trees growing in the pots which received no magnesium. First marked symptoms were edge burn and lighter green coloration of Malling IV leaves. Leaf scorch appeared shortly thereafter on Malling V and the symptoms on both stocks gradually increased in diversity and intensity. There was a distinct difference in the most prevalent type of scorch on the two stocks. Whereas the burn of Malling IV was typically leaf edge burn, that of the Malling V leaves was largely intervenal in character, resulting in irregular dead areas on the leaf blade. On July 18, leaves were taken for ash analyses. Table I summarizes some of the data of this experiment.

Untreated soil was analyzed for exchangeable bases with the following results expressed in milli-equivalents per 100 grams of dry soil: calcium — 1.36, magnesium — 0.055, potassium — 0.116. The very low value for exchangeable magnesium in the soil, 6.69 parts per

TABLE I—INFLUENCE OF DIFFERENTIAL FERTILIZATION ON SOME ASH CONSTITUENTS OF LEAF DRY MATTER, AND ON THE SEVERITY OF LEAF SCORCH SYMPTOMS ON TWO MALLING STOCKS GROWN IN CROCKS IN THE GREENHOUSE (1942)*

Malling Stock	Treatment	Quick Soil Test for Mg March 16	Soil pH	Scorch May 1	Per Cent of Dry Matter of Leaves			
					Ash	Ca	K	Mg
IV	K (1)	Low	4.6	Very severe	9.42	0.76	3.91	0.28
V	K (1)	Low	4.6	Very severe	9.54	0.96	3.83	0.23
IV	N–K (2)	Low	4.9	Very severe	8.75	0.84	3.37	0.25
V	N–K (2)	Low	4.9	Very severe	9.58	1.13	3.37	0.26
V	N–P–K (3)	Low	4.6	Severe	11.67	1.10	4.25	0.35
V	K–Mg (4)	Medium high	4.8	Medium	7.68	1.01	2.56	0.47
V	N–K–Mg–Ca (5)	Medium high	5.5	None	8.51	1.07	2.45	0.64
V	Mg (6)	Medium high	4.9	None	6.63	1.18	1.20	0.66
IV	Mg–Ca (7)	Medium	5.0	None	7.34	1.39	0.73	1.13
IV	Check	Low	4.9	Light	6.03	1.30	1.81	0.26

*Fertilizers added per pot (3 gallon capacity unless otherwise stated).

(1) KCl – 6.25 grams.
(2) $NaNO_3 + K_2SO_4$ – 6.25 grams each.
(3) $K_2HPO_4 + KNO_3$ – 3.75 grams each (2-gallon pot).
(4) $K_2SO_4 + MgSO_4$ – 6.25 grams each.
(5) $NaNO_3 + KCl + MgSO_4$ – 7.50 grams each + limestone (20 per cent MgO) – 30 grams (2-gallon pot).
(6) $MgSO_4$ – 6.25 grams.
(7) Dolomitic limestone (20 per cent MgO) – 50 grams.

million, is reflected in the magnesium leaf analyses which averaged around 0.25 per cent of the dry matter where no magnesium-carrying soil amendment was used. With added magnesium, this element was increased in the leaf tissue, and in practically every instance leaf scorch was absent. In certain cases when potassium was also present in quantity, leaf scorch typical of magnesium deficiency developed despite a fairly high percentage of magnesium in the foliage. In general, the leaves contained abundant potassium, especially following potassium fertilization. Also, the ash of magnesium-deficient foliage was relatively high.

RESULTS OF ORCHARD LEAF ANALYSES

Leaf samples were obtained from four apple varieties growing in several experimental blocks in Amherst on August 10, 1942. Within each variety leaves were taken from trees showing a gradation of foliage deficiency symptoms from none to severe. Usually, each sample consisted of leaves from two trees showing equivalent severity of scorch and defoliation. In some cases the complete sample came from one tree. The leaves were taken from the middle section of current shoot growths, and those with visible scorch were not included. In order to minimize any possible variable rootstock influence on mineral uptake and on scorch manifestation, trees growing on the same clonal rootstock were chosen for each varietal series, as far as possible. Table II gives data from these analyses.

In each of the five series (Baldwin/II, Baldwin/XV, Red Spy/V, Golden Delicious/V, and McIntosh/XVI) there is good correlation between severity of leaf scorch and the amounts of magnesium and potassium in the leaves. With magnesium, the correlation is negative; with potassium it is positive. It is also evident again that ash was higher with increased severity of scorch. It is rather remarkable that the correlations are so consistent and so free from disturbing irregu-

TABLE II—THE RELATIONSHIP BETWEEN THE SEVERITY OF LEAF SCORCH AND SOME LEAF CONSTITUENTS IN FOUR APPLE VARIETIES GROWING AT AMHERST (1942)

Sample	Variety	Malling Stock	Block	Scorch Aug 10	Per Cent of Dry Matter						Per Cent of Ash
					Ash	N	P	Ca	K	Mg	MgO
1	Baldwin	II	B	Trace	6.53	2.27	0.19	1.24	1.80	0.21	5.36
2	Baldwin	II	B	Severe	6.81	2.01	0.21	0.93	2.19	0.14	3.38
8	Baldwin	XV	Owen	None	6.68	2.06	0.18	1.32	1.92	0.23	5.69
5	Baldwin	XV	B	Trace	6.77	2.23	0.20	1.16	1.97	0.23	5.61
3	Baldwin	XV	B	Light	7.03	2.32	0.19	1.21	2.07	0.22	5.12
4	Baldwin	XV	B	Medium	7.34	2.46	0.24	0.85	2.36	0.20	4.50
6	Baldwin	XV	B	Severe	7.97	2.25	0.22	1.27	2.42	0.19	4.01
13	Red Spy	V	Owen	None	6.31	2.41	0.16	1.28	1.80	0.26	6.81
9	Red Spy	V	B	Trace	6.86	2.50	0.24	1.41	1.83	0.15	3.64
10	Red Spy	V	B	Light	7.14	2.60	0.22	1.39	1.96	0.11	2.52
11	Red Spy	V	B	Medium	7.35	2.47	0.29	1.13	2.26	0.10	2.31
12	Red Spy	V	B	Severe	7.27	2.42	0.25	1.00	2.27	0.10	2.34
19	G. Delicious	V	Owen	None	7.39	2.39	0.20	1.71	1.77	0.35	7.84
14	G. Delicious	V	B	Trace	5.72	2.34	0.19	1.34	1.72	0.18	5.24
15	G. Delicious	V	B	Light	6.35	2.37	0.22	1.20	2.15	0.10	2.68
16	G. Delicious	V	B	Medium	6.77	2.30	0.23	1.13	2.32	0.09	2.22
17	G. Delicious	V	B	Severe	7.58	2.27	0.25	1.39	2.54	0.09	1.98
28	McIntosh	XVI	D	None	6.14	2.00	0.15	1.16	1.46	0.30	8.14
23	McIntosh	Seedling	Clark	None	6.52	2.13	0.17	1.70	1.59	0.25	6.46
22	McIntosh	I	D	Light	7.23	2.11	0.16	1.15	1.62	0.17	4.59
21	McIntosh	XVI	B	Light	6.10	2.00	0.19	1.03	1.86	0.17	4.29
20	McIntosh	XVI	B	Medium	6.35	1.99	0.22	1.18	2.14	0.14	3.18
30	McIntosh	Leaves from same shoots from severely scorched tree		Healthy	6.59	2.37	0.20	0.78	2.15	0.15	3.79
29	McIntosh			Scorched	7.42	2.30	0.18	0.98	2.33	0.11	2.43

larities. Incidentally, analyses of leaves from trees in a commercial orchard in South Amherst show a similar situation.

The data for all four varieties seem to show that, on the basis of dry matter, a magnesium content of 0.25 per cent is near the critical level for magnesium in apple foliage. This is the equivalent of 0.41 per cent MgO. With the possible exception of Baldwin/XV, varietal differences are not marked. Of the healthy trees showing no scorch, Red Spy and Baldwin seem to have less magnesium than McIntosh and Golden Delicious. With Baldwin/XV, the variation in the magnesium content of leaf dry matter is very small, ranging from 0.23 showing no deficiency symptoms to 0.19 showing severe symptoms. However, on the basis of the percentage of the ash, the MgO figures show relatively greater differences — from 5.69 to 4.01, due largely to the greater amount of ash in the leaves from severely scorched trees.

The potassium data show an abundance of this element in all of the samples. With each variety, the percentages of potassium, as well as the actual amounts, are higher in leaves from trees showing deficiency symptoms. In each series there is positive correlation between leaf potassium and foliage scorch.

In percentage of dry matter the nitrogen, phosphorus, and calcium contents of leaves show no consistent trend relating to the prevalence and comparative severity of the deficiency symptoms. However, with some inconsistencies, calcium tends to follow magnesium.

Leaf samples 30 and 29 were taken from the same severely scorched McIntosh tree. Sample 30 consisted of apparently healthy leaves, while in sample 29 only leaves showing visible scorch were included. The leaves showing deficiency symptoms were high in ash and low in magnesium in comparison with the unscorched leaves.

DISCUSSION

The leaf tissue analyses of both the orchard trees and the pot-grown trees gives credence to the supposition that the deficiency symptoms as described are due to magnesium shortage. The data from the greenhouse experiment agree substantially with that from orchard trees. The analyses of unscorched leaves from the trees with deficiency symptoms show low magnesium, high potassium, and high ash. These findings corroborate those of Wallace in England (9, 10, 11), Kidson, Askew and Chittenden in New Zealand (5), and Hill in Canada (2, 4). Based on leaf dry matter, a magnesium content amounting to 0.25 per cent (0.41 per cent MgO) seems to be near the critical level for this element in leaves of apple trees growing on acid soils, which is in agreement with a similar conclusion by Wallace. However, at this level, the presence and the severity of deficiency symptoms evidently are dependent also on the accompanying level of potassium and perhaps the total ash. For instance, in the Golden Delicious/V series (Table II), the cause of light versus severe scorch can hardly be attributed to the insignificant difference of 0.01 in magnesium percentage. A more plausible explanation is the larger percentage of potassium in the leaf (2.54 compared to 2.15) or the greater amount of ash (7.58 compared to 6.35) which automatically causes a lower percentage of magnesium in the ash (1.98 per cent compared to 2.68 per cent MgO). When the potassium level is abnormally high as in the leaves of the potassium-fertilized trees in the greenhouse (Table I), the magnesium content of 0.25 per cent of the dry matter may not be sufficiently high to forestall the appearance of typical deficiency symptoms. Thus, in the K-Mg crocks, the trees scorched quite badly even though there was 0.47 per cent of magnesium in the leaf dry matter. This bears out Wallace's statement that "... magnesium requirements are increased when liberal supplies of potassic fertilizers are given" (10). Kidson *et al.* concluded that in some instances in New Zealand liberal fertilization with potassium developed an unfavorable ratio of available potassium to available magnesium thus reducing the intake of magnesium by the trees and bringing on an induced magnesium deficiency (5). This may help to explain the recent occurrence of the severe symptoms in Block B previously described. For some years this soil was low in available potassium, and there was never any evidence from the appearance of the trees of a shortage of magnesium. Following potassium fertilization and continued heavy mulching, the potassium in the soil and in the trees is now high and a deficiency of magnesium has become evident.

The magnesium content of soils on which apple trees suffered from an undersupply of this mineral element is low. Analyses of surface soil showed as little as 6.3 parts of exchangeable magnesium per million parts of dry soil. This is even lower than has been reported by Wallace

(10) for some deficient soils in England and by Hill (4) for low magnesium soils in the Frelighsburg District of Quebec. In New Zealand, less available magnesium was found on fertilized than on unfertilized soil. It was concluded that applications of bases such as potash may have reduced the amount of available magnesium, "... owing to replacement from the soil complex followed by leaching of the replaced magnesium" (5).

The question naturally arises as to why magnesium deficiency symptoms became so much more prevalent and severe in Massachusetts in 1941 and 1942 than in previous years. During the late summer of 1942, well-developed symptoms were identified in orchards fairly well scattered over the State. Many of these orchards are growing on light sandy "open" soils poorly supplied with bases. In practically all cases the soils are very acid. In some orchards where there is wide soil variation from area to area, it is evident that it is in the poorer locations (eroded, sandy, drouthy, shallow, and so on) that the trees show deficiency symptoms first and most severely.

Several factors may help to explain the apparent increased prevalence of magnesium deficiency symptoms in the last two years, aside from the possibility that the trouble has been seen for many years without positive diagnosis. First, the greatly increased usage of potassium in orchard fertilization in recent years may have caused a build-up to such a point as to accentuate the need for magnesium. In soils having a low level of magnesium, the evidence seems to indicate that potassium fertilization, even through heavy mulching alone, may so raise the level of available potassium in the soil as to bring about an actual shortage of magnesium with the resultant deficiency symptoms. This was strikingly evident with the pot-grown trees (Table I). The behavior of Block B further substantiates this theory, which has also been suggested by Wallace (10), Kidson *et al.* (5), and Hill (4). Second, the trend toward increased use of the mild sulfur sprays and of sulfur dusts has resulted in the tendency toward increased soil acidity due to the comparatively greater amounts of sulfur deposited on and leached into the soil. This factor of soil acidity may not be directly causal in relation to magnesium deficiency (although high acidity may tend to reduce availability), but it is under the more acid soil conditions that the deficiency has been prevalent in Massachusetts orchards. Third, there may be a significant relation between weather conditions and the amount of magnesium in a low-magnesium soil that becomes available and remains available to plants during the growing season. For instance, excessive rainfall has been known to cause serious leaching out of available magnesium and to enhance magnesium deficiency symptoms in crops growing on a low-magnesium soil.

Certainly it seems that the most critical factor in determining whether apple trees will or will not show magnesium deficiency symptoms is the available magnesium content of the soil. Where it is low, and especially where potassium is being used freely, magnesium fertilization may be needed and in many cases should prove profitable. A soluble salt such as magnesium sulfate (epsom salts) should correct the deficiency although experience has indicated that recovery may be slow. In New Zealand, injection of magnesium sulfate into branches of affected trees prevented the appearance of magnesium deficiency symptoms (5), which suggests that, in time, soil applications should be effective. Also the general use of adequate applications of high magnesium (dolomitic) limestone should be encouraged. This practice would not only bring about more favorable soil reactions in many orchards, but should aid in prolonging the duration of effect of the more soluble materials. Studies along this line are underway and it is hoped that recommendations based on results of experimental work can be given within a reasonable time.

Summary

Foliage scorch symptomatic of magnesium deficiency has become more or less prevalent and in some cases serious in certain apple orchards in Massachusetts. Other symptoms noted included yellow banding and mottling of leaves, abnormally early and sudden leaf fall of the older affected leaves, and with bearing trees, increased severity of preharvest drop of fruit. Symptoms varied considerably with different varieties. With two greenhouse-grown Malling stocks, one showed characteristic leaf edge burn while the scorch of the other was largely intervenal.

Chemical analyses of unburned leaves from trees showing variable degrees of foliage scorch and leaf fall showed that there was consistent correlation between symptom severity and the content of magnesium and potassium. The data suggested strongly that potassium fertilization enhanced the probability of increased prevalence and severity of magnesium deficiency symptoms. Data for four varieties indicated that 0.25 per cent dry matter of the leaf was near the critical level for magnesium in orchard trees. However, this amount was insufficient to prevent the appearance of deficiency symptoms when the potassium level was very high as in the K-fertilized pots.

The magnesium-deficient soils under consideration were quite acid and contained very small amounts of exchangeable magnesium.

It is suggested that chemical analysis of apple leaves is an accurate and direct method of determining the magnesium status of apple trees and the consequent need for remedial measures. Where deficiency symptoms are prevalent and severe, it seems that a magnesium fertilization program is called for. Also, in such orchards it would seem wise to discontinue temporarily the use of potassium in the fertilization program.

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Incipient Magnesium Deficiency in Some New York Apple Orchards[1]

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THIS paper is a report on studies of an interveinal leaf blotch occurring in several New York apple orchards. The leaf blotch is like that described, and attributed to magnesium deficiency, by Wallace (3), by Kidson, Askew, and Chittenden (2), and by Davis and Hill (1). In one mature New York orchard, injection, spraying, and soil applications of magnesium salts have seemed to reduce the prevalence and severity of the symptom. In a second New York orchard of 3-year-old apple trees, soil application of epsom salts have seemed to be a partially effective control measure.

THE SYMPTOMS

Visible Symptoms:—The visible symptom does not appear until July or later. The first evidence of abnormality is a fading between the veins of the older leaves on some shoots or spurs (see Fig. 1). The faded areas in leaves of McIntosh and Cortland trees often turn a very pale yellow; loss of green color does not seem to proceed this far in

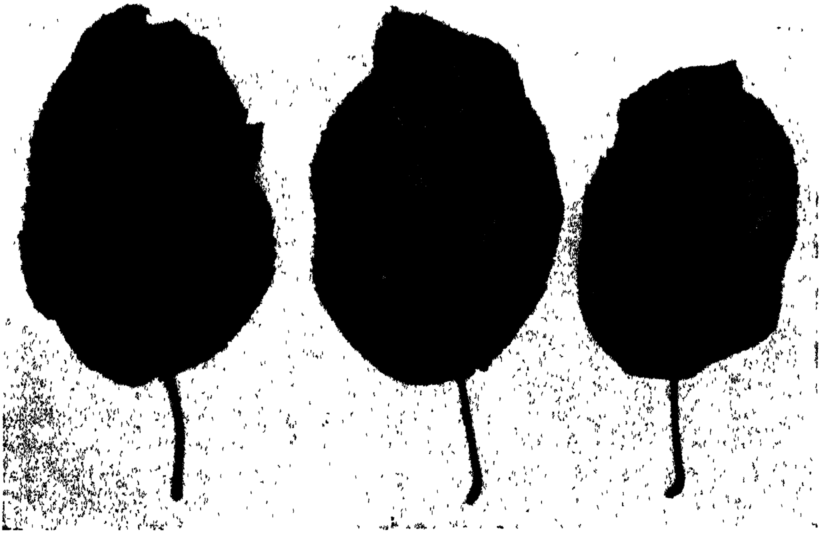

FIG. 1. McIntosh apple leaves sampled in July 1941 showing the early stage of magnesium-deficiency leaf blotch. The regions between the veins and at the leaf margin turn brown and die following the loss of chlorophyll. Some necrosis is evident in the two outer leaves.

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[1] The authors acknowledge with thanks the assistance of Dr. Walter Reuther in initial field work, of Mr. O. C. Compton in some of the analytical work, and of Mr. H. Hill whose suggestions in correspondence from the Central Experiment Farm, Ottawa, Canada, were very helpful.

the leaves of Baldwin and Northern Spy trees before death of the faded zones occurs. In leaves of all four varieties, necrosis follows fading and causes the typical brown blotches between the veins. If the fading has occurred close to the leaf margin, several blotches may overlap, producing a marginal scorch indistinguishable from that caused by potassium deficiency or toxic spray or fertilizer materials. On a severely affected branch, the older leaves may become completely shriveled and may absciss by early September, leaving the branch, which appeared normal in June, bare except for a few leaves close to the terminals of the shoots. Such loss of effective leaf surface is followed by heavy preharvest drop, and by failure of the fruit to mature normally. But in one orchard the trouble has persisted for more than 15 years without seeming to have an adverse effect on the blooming or vegetative growth of the trees involved.

The trees in affected orchards may vary greatly in the degree to which the symptom is manifested, but McIntosh trees under observation for two years were consistent in the relative severity of blotch shown. However, the weather seems to influence the time when the leaves begin to fade and blotch, and the severity of blotch in a given year. In one McIntosh block under study, the symptom did not show up until after mid-August of 1940, a year when the McIntosh bloom was delayed until the third week of May, and when the rainfall in the growing season was rather high. In 1941, the bloom began on the first of May, and the leaf blotch symptom was first apparent in mid-July. In 1941, also, the growing season was exceptionally dry. In 1942, precipitation during the growing season was well above average, but the bloom was as early as in 1941, and leaf blotch was beginning to appear on July 10. This seems to suggest that the time of bloom is more important in determining when blotch will appear than is rainfall.

Chemical Analysis of Leaves:—The percentage of magnesium found in median shoot leaves sampled in July seems to be considerably lower in McIntosh orchards where blotch occurs than in orchards not affected by it. In 1941, the mean magnesium content of leaves sampled in that way from 204 McIntosh orchards was 0.27 per cent of dry weight. The leaf samples from six of these orchards contained less than 0.15 per cent magnesium. Some blotch was evident in all six orchards in September 1941 and was a serious problem in two of them. A little leaf blotch was observed in 10 other McIntosh orchards in September 1941 or 1942. The magnesium content of leaf samples from eight of those orchards was below 0.20 per cent and in the other two was below 0.22 per cent. However, there seems to be a reciprocal relationship between magnesium and potassium as per cent of dry weight in leaves (see Table I) and until that is thoroughly investigated the usefulness of chemical analysis as a criterion of magnesium deficiency will remain in question.

RESPONSES TO MAGNESIUM IN NEW YORK

Injections:—When branches of 25-year-old McIntosh and Golden Delicious apple trees were paired according to the time of first appearance and severity of leaf blotch, and injections of epsom salts were made after the appearance of the blotch but before it had developed very far, the injections seemed to halt the development of the symptoms. Table I summarizes the results of 14 injections made in an orchard in Orange County, New York, in 1942 (treatments 47 to 60).

While injection was of value in diagnosis of the trouble, it did not seem to hold much promise as a control measure, because severe injury to the current season's leaves occurred with small overdoses, and because there did not seem to be a satisfactory carry-over from one year to the next, when moderate doses were used. Three branches showing benefit from injection in 1941, were better in appearance in 1942 than other branches on those trees, but the injected branches

TABLE I—RESPONSES OF APPLE TREES TO INJECTIONS WITH EPSOM SALTS (PAULHAMIUS ORCHARD, ORANGE COUNTY, 1942)

Number	Variety	Treatment	Constituents in Shoot Leaves† (Per Cent Dry Weight)			Observations‡
			Mg	Ca	K	
			Injections Made July 10, 1942			
47	McIntosh	Injected*	0.34	1.57	1.98	Some leaf injury§. No blotch
		Uninjected	0.03	1.12	2.48	Severe blotch
48	Golden Delicious	Injected	0.53	1.91	1.40	Some leaf injury; no blotch
		Uninjected	0.03	1.64	2.18	Severe blotch
49	Golden Delicious	Injected	0.18	1.57	1.76	Slight blotch
		Uninjected	0.05	1.79	2.14	Severe blotch and loss of leaves
50	McIntosh	Injected	0.09	1.14	1.78	Slight blotch
		Uninjected	0.04	1.04	1.74	Severe blotch and loss of leaves
51	McIntosh	Injected	0.23	1.38	1.79	Slight blotch
		Uninjected	0.03	1.27	1.97	Severe blotch and loss of leaves
52	McIntosh	Injected	0.38	1.16	1.51	Severe leaf injury. No blotch
		Uninjected	0.07	1.30	1.81	Severe blotch
			Injections Made July 22, 1942			
53	McIntosh	Injected	0.17	1.48	1.53	Moderate blotch
		Uninjected	0.06	1.35	1.61	Severe blotch
54	McIntosh	Injected	0.18	1.34	1.89	Moderate blotch
		Uninjected	0.05	1.24	2.52	Severe blotch and loss of leaves
55	McIntosh	Injected	0.33	1.52	1.54	Slight blotch
		Uninjected	0.05	1.34	2.01	Severe blotch
56	McIntosh	Injected	0.21	1.57	1.71	Some leaf injury; no blotch
		Uninjected	0.04	1.43	2.14	Slight blotch
57	McIntosh	Injected	0.17	1.44	1.88	Slight blotch
		Uninjected	0.04	1.27	1.73	Severe blotch
58	McIntosh	Injected	0.17	1.08	1.56	Slight blotch
		Uninjected	0.05	1.20	1.82	Moderate blotch
59	McIntosh	Injected	0.16	1.36	1.64	Slight blotch
		Uninjected	0.06	1.13	1.71	Moderate blotch
60	McIntosh	Injected	0.18	1.19	1.25	Slight blotch
		Uninjected	0.08	1.08	1.47	Moderate blotch
			Injections Made July 31, 1941			
37	McIntosh	Injected	0.06	1.22	2.25	Moderate blotch
		Uninjected	0.04	1.05	2.23	Severe blotch
39	Golden Delicious	Injected	0.08	1.38	1.65	Moderate blotch
		Uninjected	0.05	1.39	2.06	Severe blotch
40	McIntosh	Injected	0.07	1.01	1.99	Moderate blotch
		Uninjected	0.02	1.22	2.58	Severe blotch

*Two liters of $MgSO_4$ solution introduced into ⅜ inch hole bored in branch at least three feet from point of origin. Treatments 37, 39, 40 and 47 to 52 inclusive received 0.05 N solution; the rest received 0.025 N solution.

†Samples of 50 median shoot leaves taken September 1, 1942 except for treatment 47 which was sampled August 1, 1942.

‡All observations made September 1, 1942. Since the treatments were made following the appearance of the symptom on leaves of the branches selected for injection and the check branches, there was some blotch on the injected branches when the observations were made. The statement "no blotch" means no blotch that appeared to develop after the time of injection.

§Leaf injury appeared as a well-defined marginal necrosis similar to cyanamid injury.

showed much more leaf blotch in 1942 than in the year of injection. The magnesium contents of leaves from these trees, sampled September 1, 1942, are presented in Table I (treatments 37, 39, and 40). Leaves from the injected trees were only very slightly higher in magnesium a year after the time of injection than were leaves from check branches.

Spraying:—When moderately affected 18-year-old Cortland apple trees were paired according to the degree of leaf blotch in the previous growing season, and half of them were drenched with 2 per cent epsom salt solution four times at 2-week intervals starting in mid-June, the symptom appeared on only 10 per cent of the sprayed trees whereas it was evident on 95 per cent of the unsprayed checks. Table II summarizes the results of the spraying experiment.

TABLE II—SPRAYING OF MAGNESIUM DEFICIENT CORTLAND APPLE TREES IN RELATION TO LEAF ANALYSIS AND DEVELOPMENT OF BLOTCH (1942)*

Composite Sample†	Magnesium Content of Leaves (Per Cent Dry Wt)				Pair	Amount of Blotch Observed on Sep 1, 1942	
	Before First Spray		Before Fourth Spray‡				
	Sprayed	Unsprayed	Sprayed	Unsprayed		Sprayed	Unsprayed
					1	Slight	Moderate
					2	None	Moderate
					3	None	Slight
					4	Slight	Slight
Composite 1–5	0.15	0.17	0.25	0.11	5	None	Moderate
					6	None	Moderate
					7	None	Moderate
					8	None	Moderate
					9	None	None
Composite 6–10	0.16	0.15	0.27	0.14	10	None	Slight
					11	None	Moderate
					12	None	Slight
					13	None	Moderate
					14	None	Moderate
Composite 11–15	0.15	0.14	0.26	0.12	15	None	Slight
					16	None	Moderate
					17	None	Moderate
					18	None	Slight
					19	None	Moderate
Composite 16–20	0.14	0.15	0.27	0.14	20	None	Moderate

*Twenty trees showing moderate blotch in 1941 were paired according to similarity of size and symptoms in 1941. One of each pair was sprayed four times in 1942; 10 gallons of 2 per cent epsom salts were used for each application. The sprays were applied June 10, June 30, July 13 and August 2.

†Twenty median shoot leaves were taken from each of five trees and composited to make a single sample of 100 leaves. The numbers refer to the numbers of the trees sampled; thus composite 1-5 was taken from trees 1, 2, 3, 4, and 5.

‡The leaves were not washed but there had been heavy rains since the third spray, and no spray residue was apparent on the leaves.

While this experiment indicates that spraying seems to hold some promise as a temporary control measure in orchards showing moderate leaf blotch, its possibilities in more seriously affected orchards have not been explored under New York conditions.

Soil Applications:—Some apparent effects of soil treatments for the control of the leaf blotch symptom are summarized in Table III. The soil in both orchards in which soil treatments have been made is very acid. In Paulhamius orchard plot 1, the mean pH of surface soil samples from beneath check trees was 4.2. Its mean exchange capacity was 9.8 me/100 g soil with calcium accounting for 1.2, magnesium

TABLE III—SOIL TREATMENTS WITH MAGNESIUM SULFATE AND OTHER SALTS IN RELATION TO LEAF ANALYSIS AND DEVELOPMENT OF LEAF BLOTCH ON McINTOSH APPLE TREES

	Constituents in Leaves* (Per Cent Dry Weight)			Trees in Treatment	Trees Showing Blotch‡			
	Mg	K	Ca		Severe	Moderate	Slight	None
Paulhamius Plot 1. Forty-two 25-Year-Old McIntosh Apple Trees in an Area Showing Moderate Symptoms in 1939								
Check	0.11	2.06	0.99	12	3	1	5	3
+ Mg (two applications per year of 4 pounds Com'l $MgSO_4$, 1940, 1941, 1942)	0.17	2.01	0.98	19	0	0	7	12
+ Mg + Ca (Same Mg as above + 100 pounds annually of hydrated lime)	0.21	1.85	1.13	5	0	0	0	5
+ Ca (100 pounds hydrated lime 1940, 1941, 1942)	0.15	1.79	1.12	6	0	0	3	3
Paulhamius Plot 3.† Three Pairs of 25-Year-Old McIntosh Apple Trees Moderately Affected in 1941								
Check Pair 1	0.07	1.79	0.96	1	1	–	–	–
Mg (35 pounds Com'l $MgSO_4$ in three applications 1942)	0.08	1.95	1.10	1	-	1	–	–
Check pair 2	0.13	1.51	1.24	1	–	–	1	–
Mg (35 pounds Com'l $MgSO_4$ in three applications 1942)	0.11	1.60	1.00	1	–	–	–	1
Check pair 3	0.08	1.97	0.93	1	1	–	–	–
Mg (35 pounds Com'l $MgSO_4$ in three applications 1942)	0.13	1.69	1.07	1	–	–	1	–
Burns Plot. Forty-Two 3-Year-Old McIntosh Apple Trees Severely Affected in 1941								
Check	0.10	1.96	0.66	12	7	1	1	3
+ Mg (three applications of 2 pounds Epsom salts 1942)	0.19	1.72	0.62	9	0	0	3	6
+ Mg + K (three applications of 2 pounds Epsom salts, 2 pounds Com'l KCl 1942)	0.19	2.38	0.73	9	1	4	3	1
+ K (three applications of 2 pounds Com'l KCl 1942)	0.07	2.56	0.54	12	8	3	1	0

*Average of two composite samples of median shoot leaves sampled in mid-summer, 1942.
†The trees were paired according to similarity of symptoms developing in 1941.
‡Observations made at Paulhamius plots September 1, 1942, at Burns plot July 17, 1942.

0.1, and potassium 0.2. In the Burns orchard plot the mean pH of surface soil samples from under check trees was 3.9. The mean exchange capacity was 8.6 me/100 g soil with calcium accounting for 0.54, magnesium 0.07, and potassium 0.11.

In plot 1 of the Paulhamius orchard, mature McIntosh trees treated six times over a period of 3 years with 4 pounds of commercial magnesium sulfate fertilizer per application, were less severely affected with leaf blotch in 1942 than untreated trees, and the leaf magnesium in composite samples from the treated trees was higher than in samples from the check trees. No blotch developed on the five trees treated with both magnesium sulfate and hydrated lime, and none of the six trees treated with hydrated lime alone developed more than a slight amount of blotch. The lime applications were accompanied by higher calcium content of leaf samples, more exchangeable calcium in the surface soil samples, and higher soil pH than were found in samples from the check and from trees receiving magnesium alone, and the magnesium content of the leaf samples was higher than in samples from the check trees. The acidity of the soil and the low calcium content of the leaves from trees not treated with lime suggest that calcium deficiency may also be a limiting factor in this orchard. However, the data presented on possible responses to soil applications of magnesium and calcium in this plot are far from conclusive.

The data from plot 3 of the Paulhamius orchard indicate the difficulty encountered in obtaining response of mature trees to surface soil amendments of magnesium sulfate in 1 year, even when very large doses are made. Three applications totaling 35 pounds of magnesium sulfate made in the spring and early summer of 1942, failed to give complete control of blotch and appeared to cause little or no increase in leaf magnesium of treated trees over that in untreated trees.

Three-year-old McIntosh trees in the Burns orchard, Wayne County, to which three applications of epsom salts (at a rate of 2 pounds per tree), were made in the spring of 1942, showed much less blotch than the previous year, and markedly less than check trees. The magnesium content of the leaf samples from the treated trees was considerably higher than that of samples from the check trees. Muriate of potash applied alone, and with epsom salts may have increased the severity of the blotch symptom somewhat. Potash treatments resulted in a very sharp increase in leaf potassium. The extreme acidity of the soil, and the very low calcium content of the leaves suggest the possibility that calcium may be a limiting factor in this orchard.

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Phosphorus Deficiency in Pears[1]

By L. R. Bryant and Robert Gardner, *Colorado Experiment Station, Fort Collins, Colo.*

A SERIOUS trouble with pear trees was reported in parts of a pear orchard east of Clifton, Colorado, in 1939. It appeared in a number of pear varieties including Bartlett, Anjou and Kieffer. Distinguishing characteristics of the trouble were severe burning of the margins and the tip halves of the leaf blades early in the growing season (Fig. 1), a decrease in leaf size, failure of the fruit to develop properly, very short terminal growth, a scaly appearance of the bark, and a dying back of the new growth.

Tests for possible toxic materials including arsenic, selenium, and boron showed none of these present in sufficient quantities to account for the injury. Soil tests showed that total salts in the soil and the pH were not excessively high (1,200 to 1,300 parts per million salts and pH of 7.8). Nitrates tested about 5 parts per million. Phosphate content of the soil tested very low. The soil was also comparatively low in calcium sulphate, and tended to be very tight and puddled. Greenhouse tests with sunflowers on subsoil from this orchard showed exceptionally great response to additions of phosphorus (Fig. 2).

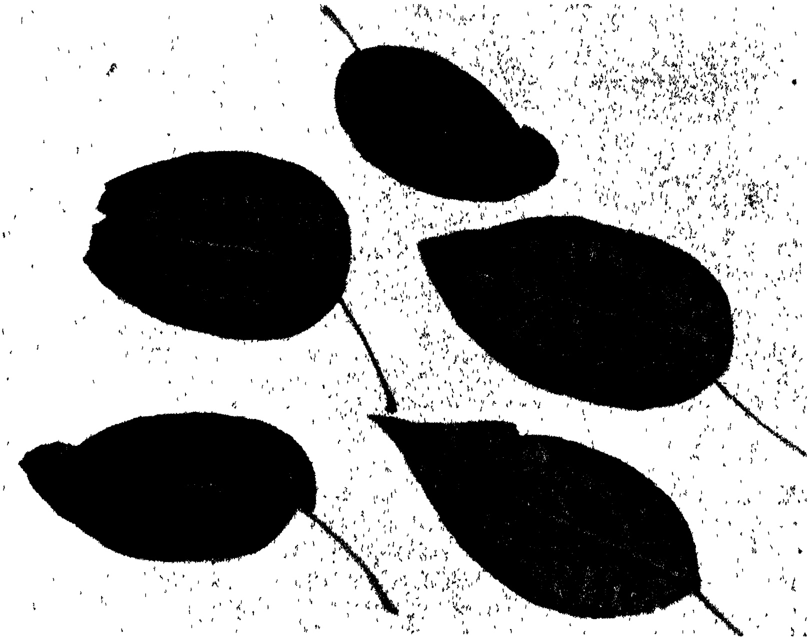

FIG. 1. Foliage symptoms of phosphate deficiency on Kieffer pear leaves.

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[1] Published with the approval of the Director as Scientific Series paper No. 158 of the Colorado Agricultural Experiment Station.

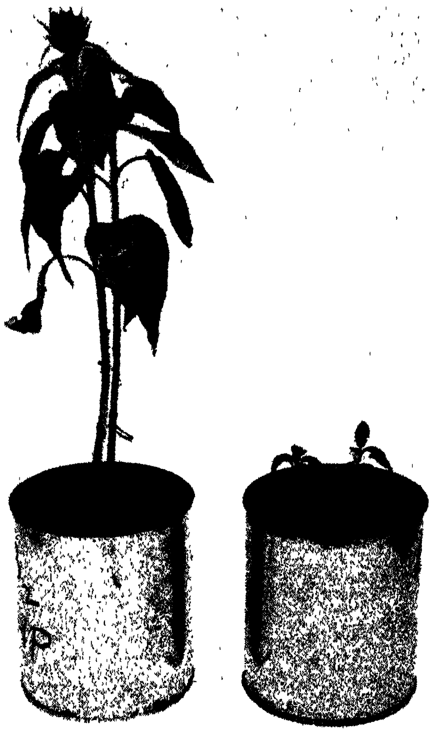

FIG. 2. Acute phosphate deficiency in sunflowers grown in subsoil from this orchard. The soil in A received phosphate and nitrogen; the soil in B received nitrogen only.

Cover crops grown in this orchard also gave increased growth from phosphate treatment.

In 1941, the grower treated some trees with a mixture of fertilizer materials including treble superphosphate, ammonium sulphate, and calcium sulphate and noted improvement in the treated trees the same year. However, no attempt was made to differentiate between the effects of the different materials used.

With funds furnished by the Mesa County Research Committee, specific fertilizer materials were applied under controlled conditions to 30 trees in the most seriously affected part of this orchard, in the spring of 1942. Applications of phosphorus, sulphur and potassium were made alone and in various combinations. The trees treated were selected with the aid of the grower on the basis of tree appearance and previous season's growth. Only seriously affected trees were included and all were of the Kieffer variety. Selections were made in the early spring before the trees had leafed out. All materials used in these treatments were put down to the root zones in auger holes. The depth varied from 12 inches to nearly 3 feet. Final foliage readings were made September 4, 1942. Treatments and quantities of materials applied were as follows:

Sulphur alone — 5, 10, and 15 pounds per tree.
Treble superphosphate alone — 5, 15, and 25 pounds per tree.
Potassium chloride alone — 2, 6, and 10 pounds per tree.
Sulphur 5 pounds and treble superphosphate 5 pounds per tree.
Sulphur 10 pounds and treble superphosphate 10 pounds per tree.
Sulphur 15 pounds and treble superphosphate 25 pounds per tree.
Treble superphosphate 5 pounds and potassium chloride 2 pounds per tree.
Treble superphosphate 15 pounds and potassium chloride 2, 6, and 10 pounds per tree.

Treble superphosphate 25 pounds and potassium chloride 10 pounds per tree.

Recovery, where treble superphosphate was used, either alone or in combinations with other materials was remarkable. Trees which in 1941 showed serious foliage, twig, and fruit symptoms appeared in excellent condition. As a result of the 1942 treatment, tree growth and leaf size and color were good. The fruit was normal and not small and knotted as it was the previous year on these trees or on untreated trees in the poorer part of the orchard. Even the lowest phosphate application, 5 pounds per tree, caused definite improvement.

The use of sulphur alone showed satisfactory improvement when not less than 10 pounds per tree were applied. The combination of sulphur with treble superphosphate gave good improvement from as little as 5 pounds of each per tree. Heavier applications gave excellent results.

There were no apparent benefits from potassium fertilizers when applied alone or in combination with the other materials.

The fact that both phosphate and sulphur corrected the trouble could be interpreted as indicating a deficiency of either phosphorus or sulphur or both since the phosphate fertilizer contained a small amount of sulphur as an impurity. However, the irrigation water, the native shales from which the soil was formed, and nearly all the soils in the Clifton area are so high in soluble sulphates that it seems improbable that there could be a deficiency of sulphur as a nutrient. Soil tests verified this. It is therefore concluded that the trouble was a result of phosphate deficiency and that the benefits from sulphur were caused by a decrease in alkalinity and a consequent increase in the available phosphorus in the soil.

Observations made in the pear producing areas between Palisade and Grand Junction early in September, 1942, show that the trouble is not limited to the section immediately around the test orchard but that isolated trees in many of the pear orchards in this valley show identical symptoms. These observations would indicate that the soil condition apparently responsible for this malady may be widespread over the valley.

In connection with the symptoms present on these pear leaves, it is of interest to note that they are very similar to phosphate deficiency symptoms which have been observed on citrus leaves (1), and resemble in many respects the symptoms of phosphate deficiency disease (black heart) in sugar beets. The increase in anthocyanin pigments, often associated with phosphate deficiency in tree fruits (2), was not observed.

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A Comparison of Certain Chemical Constituents of Green and Chlorotic Macadamia Leaves[1]

By Paul Guest, *United States Department of Agriculture, Washington, D. C.*

IN recent years many macadamia (*Macadamia ternifolia* var. *integrifolia*) trees in one commercial orchard on Oahu, T. H., and many seedlings in several nurseries have become chlorotic. In severe cases, the yield of the trees has been reduced and there has been considerable die-back of the twigs. This malcondition has been overcome in part by repeated applications of a 1 to 2 per cent iron-sulfate spray or by injecting iron salts in the trees which suggests that manifestation of chlorosis in the macadamia is associated with abnormal iron metabolism. During an investigation of several phases of the problem, certain chemical constituents of green, slightly chlorotic and chlorotic leaves were determined. The results obtained are presented herewith.

MATERIAL AND METHODS

Three samples of leaves were taken from two green trees, one slightly chlorotic tree and two severely chlorotic trees in a bearing orchard at Nutridge, Oahu, T. H., between January and September, 1938. Four samples of green, slightly chlorotic and chlorotic leaves were obtained from 6- to 9-month's-old nursery seedlings at Kailua, Oahu, during the same period. Longitudinal growth of marked twigs was measured periodically and only the youngest fully-sized leaves of comparable chronological age were sampled. The hour of sampling was approximately the same on each date.

For reference purposes, the healthy, green leaves were similar to the color of plates 22–L–5 to 22–L–8 in a Maerz and Paul (5) color dictionary; slightly chlorotic leaves ranged from the color of plate 20–L–1 to the color of 21–L–5; and the chlorotic leaves varied from 17–J–1 to the color of 17–L–4. Ash, iron, manganese, calcium, magnesium, potassium and phosphorus determinations were made on all of the samples and certain carbohydrate and nitrogen fractions were estimated on two samples.

Sideris' colorimetric methods were used for estimating manganese (11), magnesium (10), and potassium (9). Iron (2) and phosphorus (1) also were determined colorimetrically. The usual ammonium oxalate-potassium permanganate method was used for calcium.

An 80 per cent alcoholic extract of fresh leaf material was used for estimating the soluble carbohydrate and nitrogen fractions and the residue was used for certain insoluble fractions. For sugars, the extract was cleared with neutral lead acetate and deleaded with potassium oxalate. Reducing sugars were estimated according to the method outlined by Stiles, Peterson, and Fred (12). Invertase was used for non-reducing sugars. Acid-hydrolyzable materials were determined by hydrolyzing the extracted residue for 2½ hours with 2½ per cent HCl.

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[1] This investigation was carried out while the author was a member of the Division of Horticulture, Hawaii Agricultural Experiment Station, Honolulu, T. H.

Total nitrogen was estimated by the micro-Kjeldahl method (8). A concentrated solution of the original extract was used for ammonia-, amid-, and amino nitrogen. Ammonia nitrogen was determined by aerating this concentrated solution in Cullen-Van Slyke tubes (4). For amid nitrogen, the solution was hydrolyzed 2 hours with concentrated H_2SO_4 and then the procedure was the same as that for ammonia nitrogen (4). Amino nitrogen was estimated by Van Slykes's method (4). The usual phenoldisulfonic acid method was used for nitrate nitrogen.

RESULTS

Although the absolute values of certain constituents varied considerably in several samples, nevertheless the trend in the composition of the leaves did not vary appreciably and therefore the data for only one sample which was obtained from 9-month's old nursery seedlings at Kailua on September 21, 1938, are presented (Table I).

The relative difference in the size of green and chlorotic macadamia leaves is reflected by the difference in their weights, green leaves being several times larger and heavier than chlorotic leaves. The percentage

TABLE I—ANALYSIS OF CERTAIN ASH, CARBOHYDRATE AND NITROGEN CONSTITUENTS OF MACADAMIA LEAVES FROM NURSERY SEEDLINGS AT KAILUA, OAHU, SEPTEMBER 21, 1938 (EXPRESSED IN UNITS PER GRAM OF FRESH TISSUE)

Item	Condition of Leaves		
	Green	Slightly Chlorotic	Chlorotic
Average weight per fresh leaf (Grams)	1.81	1.35	0.72
Dry weight (Per Cent)	44.6	43.9	39.9
Ash Constituents			
Ash (milligrams)	11.2	12.6	13.7
Iron (gamma)	3.9	3.2	2.8
Manganese (gamma)	26.0	15.0	5.1
Calcium (milligrams)	1.9	1.6	1.4
Magnesium (milligrams)	0.14	0.18	0.19
Potassium (milligrams)	3.1	3.6	3.5
Phosphorus (milligrams)	2.3	2.9	3.2
Solids			
Soluble solids (milligrams)	103.0	99.0	91.0
Insoluble solids (milligrams)	343.0	340.0	308.0
Total solids (milligrams)	446.0	439.0	399.0
Carbohydrates			
Reducing sugars (milligrams)	20.3	19.2	15.8
Non-reducing sugars (milligrams)	4.2	2.9	1.4
Total sugars (milligrams)	24.5	22.1	17.2
Acid-hydrolyzable materials (milligrams)	53.9	52.1	49.4
Nitrogen			
Soluble fractions			
Ammonia (milligrams)	0.10	0.21	0.23
Amid (milligrams)	0.22	0.31	0.35
Amino (milligrams)	0.20	0.44	0.66
Nitrate (milligrams)	0.0	0.0	0.0
Rest (milligrams)	0.85	1.27	1.46
Total soluble (milligrams)	1.37	2.23	2.70
Total insoluble (milligrams)	4.46	4.85	4.62
Total nitrogen (milligrams)	5.83	7.08	7.33

of ash was higher in chlorotic leaves than in green leaves from healthy seedlings. In most of the samples, the chlorotic leaves contained only slightly less iron than the green leaves and in one sample from bearing trees at Nutridge, the percentage of iron actually was higher in chlorotic leaves than in green leaves. Kelley and Cummins (3), Mann (6), Oserkowsky (7), and others have reported similar cases in which the percentage of iron was as high (or higher) in chlorotic or mottled leaves as in healthy, green leaves. Calculated as percentage of total fresh weight, the green leaves contained from 2 to 15 times more manganese than chlorotic leaves but calcium was only slightly higher in the former. On the other hand, chlorotic leaves were higher in magnesium, potassium, and phosphorus (Fig. 1).

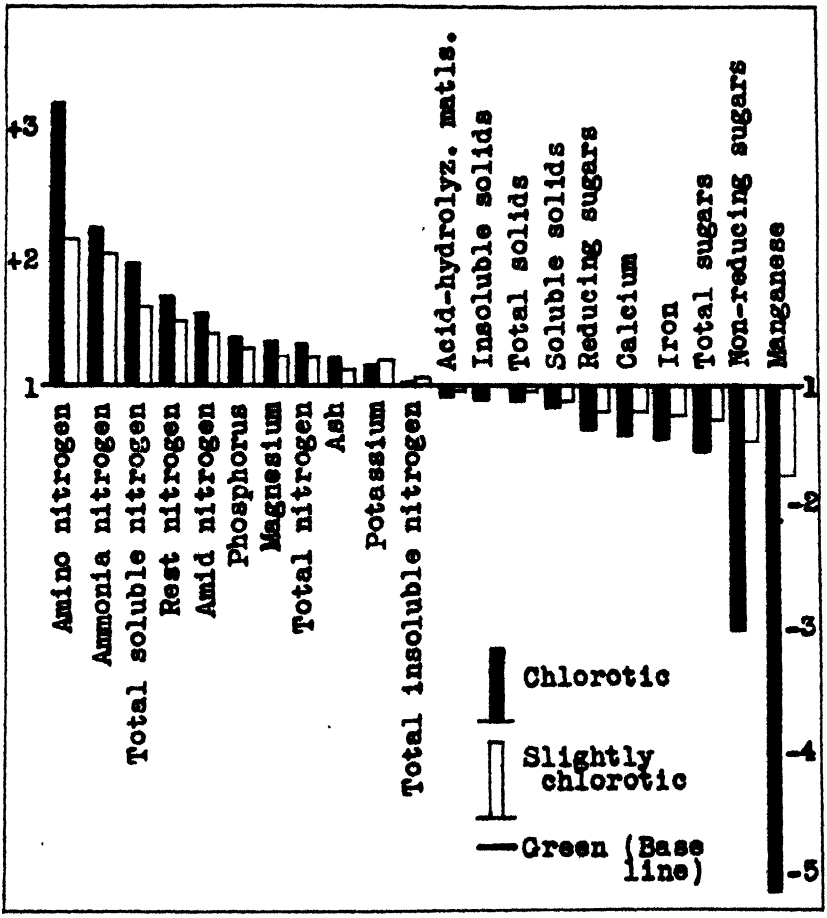

FIG. 1. Relative amount of certain leaf constituents of chlorotic and slightly chlorotic macadamia leaves in proportion to the amount in green leaves. "Plus" values obtained by dividing the values for the chlorotic and slightly chlorotic leaves in Table I by the corresponding values for the green leaves; reciprocal divisions gave "minus" values.

The green leaves had a slightly higher percentage of soluble solids, reducing sugars and acid-hydrolyzable materials, and from 3 to 14 times more non-reducing sugars than chlorotic leaves. However, the percentage of ammonia-, amid-, and amino nitrogen, especially the amino fraction, was considerably higher in chlorotic leaves than in green leaves. Tests for nitrate nitrogen were negative in all cases.

DISCUSSION

The extremely low percentage of manganese in the chlorotic leaves in proportion to the green leaves is particularly striking. However, chlorotic leaves dipped in 0.01 to 1.0 per cent solutions of manganese sulfate did not become green although there was slight injury at the higher concentration. Similar leaves treated with solutions of ferrous sulfate turned green in 10 to 20 days.

The chlorotic leaf tissue was very low in non-reducing sugars although it contained an appreciable quantity of reducing sugars. The extremely high percentage of soluble nitrogen in the chlorotic leaves in proportion to green leaves indicates that conditions within chlorotic plants favor accumulation of ammonia-, amid-, amino-, and other soluble nitrogen components but that their conversion into other forms is restricted. The proportionately high concentration of ammonia raises the question as to whether the development of necrosis in severely chlorotic macadamia leaves may be the result of the toxic effect of ammonia upon the tissue if the carbohydrate supply becomes depleted. The negative tests for nitrate nitrogen show that if nitrate is absorbed, it is reduced either before it reaches the leaves or within a short time thereafter.

SUMMARY

Seven samples of green, slightly chlorotic and chlorotic macadamia leaves from bearing trees and nursery seedlings were analyzed for certain chemical constituents. As a generalization, fresh, green leaves were considerably higher in manganese and non-reducing sugars and slightly higher in dry matter, calcium, iron, reducing sugars, and acid-hydrolyzable materials than chlorotic leaves. Conversely, chlorotic leaves were considerably higher in ammonia-, amid-, and amino nitrogen and slightly higher in ash, magnesium, potassium and phosphorus than green leaves. Tests for nitrate nitrogen were negative in all cases.

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A Study of Methods of Sampling Pecan Leaves for Total Nitrogen Analysis

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PECAN trees respond in amount and type of growth, in foliage condition, and in yield and quality of nuts to differences in soil fertility and fertilizer treatments, and to cultural treatments affecting soil nutrients and moisture (1, 4, 5). Applications of elements in which the soil is deficient, notably nitrogen, have been shown to greatly affect the chemical composition of the leaves of pecans (2) and other plants. Thomas (8) emphasizes the importance of foliage as the seat of synthetic processes in the plant and cites the work of Pierre (6) as pointing to "the sensitivity of the leaves to changes in composition resulting from differences in environment". Thomas and Mack (9) point out that utilizing the chemical composition of the leaf as a method of expressing plant performance is more reliable, and supplies more information about the factors influencing plant development and yields, than the commonly used method of relating yields directly to fertilizers and cultural treatments.

The work reported in this paper is preliminary to a more detailed study of the chemical composition of pecan foliage, and has a two-fold purpose: (a) to perfect a sampling method that can be reliably repeated, and that will be representative of trees or groups of trees growing under different environmental conditions; and (b) to determine if the samples taken by such a method can be used to measure small differences in the total nitrogen content of the leaves.

PLANT MATERIAL AND CULTURE

Two groups of 6-year-old Success pecan trees at the United States Horticultural Field Station at Meridian, Mississippi, were selected for total nitrogen study in the fall of 1940. The soil in which these trees are growing is classified in the Ruston series. One tree group, however, is on a low lying, fairly level sandy loam having a fairly good water-holding capacity, designated as area B; the other is on a knoll of sandy clay that dries out rapidly, and is referred to as area Y. Summer cover crops of legumes or of native weed growth were plowed into the soil of area B each fall from 1933 through 1940. Winter legumes were turned under every spring beginning with 1934. Summer and winter legumes were grown and plowed under in area Y each year from 1933 to 1937. In the spring of 1937 this area was planted to kudzu which was maintained continuously thereafter to control erosion.

Cross sectional areas of the tree trunks were calculated from the circumferences measured at a marked point, every year from 1937 to 1940, inclusive. The average cross sectional areas of the trunks of the trees are given by the data in Table I, and show that the trees in the two areas were widely different in rate of growth and in size attained.

The mode rather than the mean is taken as an indicator of terminal

TABLE I—Measurements and Annual Increases of the Cross-Section Areas of the Trunks of Two Groups of Success Pecan Trees of the Same Age, But with Different Environmental Conditions (United States Horticultural Field Station, Meridian, Mississippi)

	Cross-Section Area (Sq In)		Annual Increase in Cross-Section Area (Sq In)			Total Increase (Sq In)	Average Annual Increase (Sq In)
	1937	1940	1937–38	1938–39	1939–40		
Area B	2.5	17.7	2.4	5.2	7.7	15.2	5.1
Area Y . . .	1.3	5.6	0.7	1.7	1.9	4.3	1.4

shoot growth, since the length of the shoots occurring with the greatest frequency should more nearly represent the condition of the trees than an over-all average which is readily influenced by a few extremes. The shoots occurring with greatest frequency on the trees in area B were from 12 to 16 inches long, and those on the trees in area Y, 8 to 12 inches long.

The foliage in area B was heavy and green until frost in November 1940, whereas that in area Y was a paler, yellowish green and had begun to fall in September.

The first crop was borne in 1939. The average yield per tree was 0.59 pound in area B and 0.06 pound in area Y. In 1940 it was 0.51 pound in area B and nothing in area Y.

Methods

A satisfactory method of sampling pecan foliage should give material that would be: (a) representative of the trees, (b) measure accurately small differences between trees, (c) be capable of accurate repetition on the same trees, and (d) be capable of being applied to trees in different conditions and at different times.

A trial method of foliage sampling was accordingly developed. Five trees as nearly alike as possible and representative of the area were selected in area B and in area Y, respectively. The modal number of leaflets per leaf was found to be 11. One leaf, median or nearly median, having 11 leaflets and of modal length as measured from the base of the rachis to the tip of the terminal leaflet, was taken from each of four modal-length shoots, one at each major compass direction, a third to half way up the outside of each tree. Each sample from either group then consisted of 20 complete leaves, four from each of the five trees. In order to obtain all complete leaves in area Y, a few leaves having 9 or 13 leaflets had to be included. To determine accuracy of repetition, 10 samples were taken in this manner from the five trees in each area.

Ten random samples were taken from each group of trees as a check against the selective sampling method. The leaves were taken from the same part of each tree as were the selected samples, but so far as possible, without regard to the length of the shoots and leaves, number of leaflets and position of the leaves on the shoots. A tendency of the worker to take leaves from a range of types and sizes of both leaves and shoots in contrast to selecting similar types was observed, and an attempt was made to avoid any selection at all.

The leaves were weighed in closed cans, dried for 1 hour at 100 degrees C, for 48 hours at 70 degrees C, and finally for 1 hour at 100 degrees C and under a stream of dry air at a pressure of approximately 5 inches of mercury. They were then reweighed. The dried leaves were ground in a ball mill. The ground material was then allowed to stand until it reached air-dry weight, and moisture determinations were made before weighing out samples for analysis. Total nitrogen, including nitrates, was determined by the Kjeldahl-Gunning method (3).

EXPERIMENTAL PROCEDURE AND RESULTS

A series of 10 samples of complete leaves was taken in area B on August 23 and in area Y on August 24, 1940. The data on total nitrogen content, stated both as percentage of the dry matter and as milligrams per leaf, are presented in Table II. The statistical analysis of the data was made by the methods of Snedecor (7). The coefficient of variation in nitrogen percentages in each group of 10 samples was below the 5 per cent level considered good for biological material. The values for milligrams of nitrogen per leaf were just at the desirable 5 per cent level in the case of area B samples and above 5 per cent for those from area Y. The difference in nitrogen content of the leaves from the two groups of trees is shown to be highly significant in either method of presenting the data.

TABLE II—THE TOTAL NITROGEN CONTENT OF LEAVES TAKEN BY SELECTIVE SAMPLING FROM TWO GROUPS OF SIX-YEAR-OLD SUCCESS PECAN TREES (UNITED STATES HORTICULTURAL FIELD STATION, MERIDIAN, MISSISSIPPI, AUGUST 23 AND 24, 1940)

Analysis	Total Nitrogen Expressed as:			
	Percentage of Dry Weight		Milligrams Per Leaf	
	Area B	Area Y	Area B	Area Y
Mean ($\bar{x}$)	2.267	1.982	65.908	49.020
Standard error of mean ($s_{\bar{x}}$)	0.0179	0.0277	1.0386	1.2614
Standard deviation (s)	0.0565	0.0876	3.2845	3.9889
Coefficient of variation (cv)	2.49%	4.42%	4.98%	8.14%

To determine if there is any difference in accuracy of the two sampling methods, selective and random samples of leaves, including the rachises, were taken as previously described from the trees in area B on October 1, 1941. The data are presented in Table III. Although the coefficient of variation for the total nitrogen as percentage of dry matter in the random samples is below 5 per cent, it is not as low as the 2.21 per cent coefficient of variation for the 1941 selective samples or the 2.49 per cent in the 1940 selective samples.

Two series of selective samples were taken September 20 and 21, 1940, in area B to determine if the percentage of nitrogen would remain the same and the total amount per leaf be reduced in leaves from which some leaflets had been abscised, or if the total amount might be concentrated in the remaining leaflets and the percentage of nitrogen be

TABLE III—COMPARISON OF THE TOTAL NITROGEN CONTENT OF LEAVES TAKEN BY SELECTIVE SAMPLING AND BY RANDOM SAMPLING FROM A GROUP OF SIX-YEAR-OLD SUCCESS PECAN TREES (AREA B) (UNITED STATES HORTICULTURAL FIELD STATION, MERIDIAN, MISSISSIPPI, OCTOBER 29, 1941)

Analysis	Total Nitrogen Expressed as			
	Percentage of Dry Weight		Milligrams Per Leaf	
	Selective Sampling	Random Sampling	Selective Sampling	Random Sampling
Mean ($\bar{x}$)	1.995	1.876	65.645	65.393
Standard error of mean ($s_{\bar{x}}$)	0.0140	0.0188	0.6096	1.6530
Standard deviation (s)	0.0441	0.0595	3.7165	5.2272
Coefficient of variation (cv)	2.21%	3.17%	5.66%	7.99%

thereby increased. In all samples the leaves had originally eleven leaflets, but in one series two or more leaflets had already been abscised at the time of sampling. The data are given in Table IV. It will be seen that the average dry weights of the whole leaves were significantly greater than of those that had lost some leaflets. The percentage of nitrogen in the leaves with two or more leaflets missing was found to be 3.8 per cent less, and the milligram weight of nitrogen per leaf, to be 22.7 per cent less than in the whole leaves. These results would seem to indicate that the lower weight of nitrogen per leaf was due in part to a loss of leaflets, and in part to a lower percentage of nitrogen. Inasmuch as both the percentage and total weight of nitrogen are higher in complete leaves, and as the coefficient of variation for total nitrogen is less, it seems advisable to select leaves with all leaflets present. Furthermore, the data show that the percentage of nitrogen in the dry matter is much less affected by variations in leaf size than is the actual weight of nitrogen per leaf. The percentage of nitrogen on a dry weight basis would, therefore, seem to be the better measure for comparative purposes.

TABLE IV—THE TOTAL NITROGEN CONTENT OF SUCCESS PECAN LEAVES (AREA B) WITH ALL LEAFLETS PRESENT, COMPARED WITH THAT OF LEAVES WITH TWO OR MORE LEAFLETS MISSING (SEPTEMBER 20 AND 21, 1940)

Analysis	Average Dry Weight Per Leaf (Gms)		Total Nitrogen Expressed As Percentage of Dry Weight		Milligrams Per Leaf	
	All Eleven Leaflets Present	Two or More Leaflets Missing	All Eleven Leaflets Present	Two or More Leaflets Missing	All Eleven Leaflets Present	Two or More Leaflets Missing
Mean ($\bar{x}$)	2.960	2.376	2.203	2.119	65.163	50.358
Standard error of mean ($s_{\bar{x}}$)	0.0701	0.0552	0.0139	0.0279	1.463	1.397
Standard deviation (s)	0.2217	0.1746	0.0441	0.0882	4.626	4.418
Coefficient of variation (cv)	7.489%	7.424%	2.00%	4.16%	7.10%	8.77%

Samples of complete leaves having 11 leaflets were taken from area B on September 23 and from area Y on September 24, 1940, the leaflets stripped from the rachises, and leaflets and rachises analyzed separately. The differences in the nitrogen content of both the leaflets and the rachises from the two groups of trees were highly significant (Table V). However, the deviation in replicate leaflet samples, as measured by the coefficient of variation, was noticeably less than that of replicate rachis samples, whether stated as percentage or milligrams of nitrogen. The rachises were found to contain only 6 per cent of the total weight of the nitrogen in the whole leaves, although they comprised about 15 per cent of the total dry weight of the leaves. The coefficients of variation for percentage of total nitrogen on a dry weight basis were lower than those for milligrams of nitrogen per leaf.

TABLE V—THE TOTAL NITROGEN CONTENT OF LEAFLETS AS COMPARED WITH LEAF RACHISES FROM SIX-YEAR-OLD SUCCESS PECAN TREES (SEPTEMBER 23 AND 24, 1940)

Analysis	Leaflets Only				Rachises Only			
	Nitrogen as Percentage of Dry Weight		Nitrogen as Milligrams Per Leaf		Nitrogen as Percentage of Dry Weight		Nitrogen as Milligrams Per Leaf	
	Area B	Area Y	Area B	Area Y	Area B	Area Y	Area B	Area Y
Mean ($\bar{x}$)	2.491	1.979	61.528	46.403	0.816	0.691	3.715	2.872
Standard error of mean ($s_{\bar{x}}$)	0.0815	0.0134	1.125	1.771	0.009	0.014	0.0761	0.0913
Standard deviation (s)	0.0584	0.0425	3.557	5.602	0.030	0.045	0.2405	0.2887
Coefficient of variation (cv)	2.34%	2.15%	5.78%	12.07%	3.63%	6.47%	6.47%	10.05%

In view of the facts that the leaflets contain 85 per cent of the dry matter and 94 per cent of the nitrogen of the entire leaves, that leaflet samples are more accurately replicated than either rachis or whole leaf samples as regards percentage of nitrogen, that they probably reflect the metabolic processes of the leaves better than the rachises, and that they are more conveniently handled than whole leaves, leaflets seem to be the best material to use for determining the nitrogen content of pecan foliage for comparative purposes.

The accuracy of sampling pecan foliage by taking leaflets from modal length leaves with the modal number of leaflets and borne on modal length shoots for any tree group or treatment, and presenting the data as percentage of nitrogen on a dry weight basis, may be seen by examining the data in Table V. The coefficients of variation of 10 samples each in area B and in area Y are 2.34 per cent and 2.15 per cent, respectively. Both of the values are less than half of the maximum of 5 per cent considered by Snedecor (7) to be satisfactory. Furthermore, small differences in total nitrogen content of leaves may be measured by this method. The mean difference required for significance at the one per cent level is .066, slightly less than 3 per cent of the mean total nitrogen percentage of the foliage from both groups of trees. The analyses show a difference of .512 between percentage values for total nitrogen in the foliage from the two groups of trees, nearly eight times that required for significance, thus clearly showing a relation between the nitrogen content of the foliage and those conditions within the trees that influence growth and fruiting.

SUMMARY

A method of sampling pecan foliage, based on selection of the most frequently occurring (modal) length of terminal shoots, length of leaves, and number of leaflets per leaf, was developed for obtaining accurate replications of representative samples for total nitrogen analyses.

The leaflets stripped from the rachises were found to be the most convenient type of material as well as to yield highly accurate results as measured by low coefficients of variation in two series of 10 samples each from trees in two distinct conditions of growth and fruiting.

The percentage of total nitrogen on a dry weight basis was found to give more consistent results than milligrams of nitrogen per leaf because of being less affected by variations in leaf size, and it is therefore considered to be the better value for comparative purposes.

It is shown that differences as small as 3 per cent of the mean can be measured accurately by the method described, and these may be considered highly significant.

The total nitrogen content of the leaves of 6-year-old Success pecan trees with a general terminal growth length of 12 to 16 inches, and just coming into bearing, was noticeably greater than that of trees of the same age, growing under less favorable conditions, and having a general terminal growth length of 8 to 10 inches and bearing few or no nuts.

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The Influence of Date of Sampling on the Value of Leaf Weights and Chemical Analyses in Nutrition Experiments with Apple Trees[1]

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THE nutritional experiment with apple trees grown in metal cylinders recently completed at this station afforded a unique opportunity to study the interrelationships between chemical analyses of portions of the trees, physical measurements of the same trees, and their fertilizer treatment. The detailed reports of this experiment have been prepared, and will be published shortly. It is the purpose of this paper to present a study of the time of leaf sampling and its relation to the physical and chemical measurements made on these leaves, specifically the leaf weights and the nitrogen analyses of the leaves.

EXPERIMENTAL PLAN

Trees and Treatments:—The trees used in this experiment were of the Stayman Winesap variety, budded on Malling XII stock. Metal cylinders, 5 feet in diameter and 5½ feet deep, were set into the ground so that the upper edge extended approximately 6 inches above the surface of the surrounding earth. The bottoms of the cylinders were closed with concrete, allowing a drainage opening in the center, and were filled with Hagerstown silty clay soil dug and placed in the cylinders in three layers: surface 0 to 9 inches, subsurface 9 to 18 inches, and subsoil 18 to 48 inches. Forty-two of these cylinders were arranged in six rows of seven columns each, and one tree was planted in each cylinder in the spring of 1928. During 1928 and 1929 all of the trees received a uniform treatment of adequate amounts of nitrogen, phosphorus and potassium.

Beginning with the growing season of 1930, differential treatments were applied. For convenience the rows were designated by letters, the columns by figures. Row A received no inorganic nitrogenous fertilizer; row B, one unit; row C, two units, and so on, row F (the last) receiving five units of nitrogen. During subsequent years the amounts and chemical nature of the nitrogenous fertilizers applied were varied, but the relations between the rows was not. The columns, running from 1 to 7, received increasing amounts of green manure applications, column 1, none; column 2, one unit; column 3, two units, and so on, through column 7, which received six units of green manure. Thus each of the 42 trees in the experiment received a different treatment ranging from tree A-1 which received neither nitrogen nor green manure through tree F-7 which received five units of nitrogenous fertilizer and six units of green manure. Each tree in the experiment received uniform amounts of potassium and phosphorus in the form of inorganic fertilizers in amounts considered to be adequate for the size of the trees. The trees were grown in the cylinders until the autumn of 1938, at which time they were removed, weighed and sampled.

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Sampling:—Several times during each growing season from 1932 through 1938 leaf samples were taken from a point midway on the terminal growth. No more than one leaf was taken from a terminal at any given sampling, and in most cases only one leaf was taken from a terminal per season. Usually four samples were taken, the first during late May or early June, the second during July or August, the third usually in September, and the fourth near the end of the growing season, usually in October. The exact dates of sampling and the number of leaves taken are given in Table I.

TABLE I—DATES OF SAMPLING AND NUMBER OF LEAVES TAKEN FROM EACH TREE

Year	Date	Number of Leaves
1932	May 18	36
1932	June 17	25
1932	August 2	20
1932	September 22	20
1933	June 29	20
1933	August 3	15
1933	September 1	15
1933	October 3	15
1934	June 4	20
1934	July 6	20
1934	August 2	20
1934	August 31	15
1934	October 17	15
1935	May 27	80*
1935	July 8	100*
1935	August 23	30
1935	October 3	30
1936	June 4	100*
1936	July 8	100*
1936	August 24	30
1936	October 2	40
1937	June 8	100
1937	July 13	80*
1937	August 24	30
1937	October 6	30
1938	June 15	100*
1938	August 18	100*
1938	September 26	100†

*Samples of the entire one year (terminal) growth collected and all leaves removed for analysis. The average number of leaves is indicated.

†Final sample taken at the time the trees were removed from soil. Two samples—spur leaves as well as terminal leaves—were collected at this time.

The leaves were taken to the laboratory immediately after collection, and were weighed after removal of the petioles. They were then dried in an air oven at approximately 80 degrees C until thoroughly dry, and were then removed, allowed to come to equilibrium with respect to the moisture in the air, and were again weighed and ground for analysis.

EXPERIMENTAL RESULTS

Only a portion of the experimental results will be given in this paper, those having a bearing on the relation between sampling date, chemical analyses and fertilizer treatment. More complete information on other

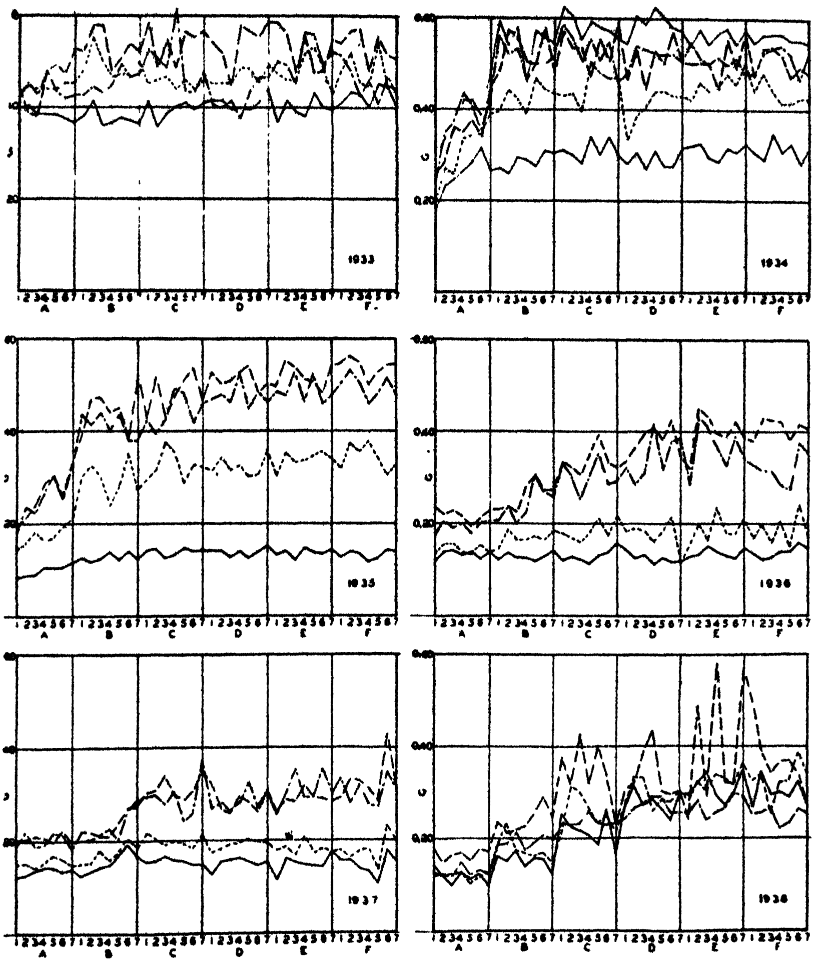

FIG. 1. Air-dry leaf weights for all samples taken, 1933 to 1938, inclusive.

phases of the experiment may be found in the detailed reports presented elsewhere[2] at a later date.

Leaf Weights:—The air-dry leaf weights for all of the samples taken during the years 1933 to 1938 inclusive are given in Fig. 1. In each of the charts in this figure the solid line represents the first sampling, the short dotted line the second, the long dotted line the third, and the alternately long and short dotted line the fourth sampling. In 1934 a fifth sample was taken, represented by a lighter solid line.

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[2] Response of Stayman apple trees in metal cylinders to varying amounts of inorganic nitrogenous fertilizers and green manures.

Part I. The influence of the various treatments on tree performance and the physical condition of the soil. Anthony, R. D., Fagan, F. N., and Clarke, W. S., Jr.

Part II. Chemical studies on the nitrogenous metabolism. Frear, D. E. H.

Part III. Chemical studies on the phosphorus metabolism. Frear, D. E. H.

Part IV. Chemical studies on the potassium metabolism. Frear, D. E. H.

Part V. Soil studies. Richer, A. C., and White, J. W.

Leaf Nitrogen:—For comparison with the leaf weight data the amounts of nitrogen present in the leaf samples are presented in Figs. 2 and 3. In Fig. 2 the amounts of nitrogen are expressed as percentages of the air-dry leaf weights; while in Fig. 3 the amounts are expressed as milligrams of the element per leaf.

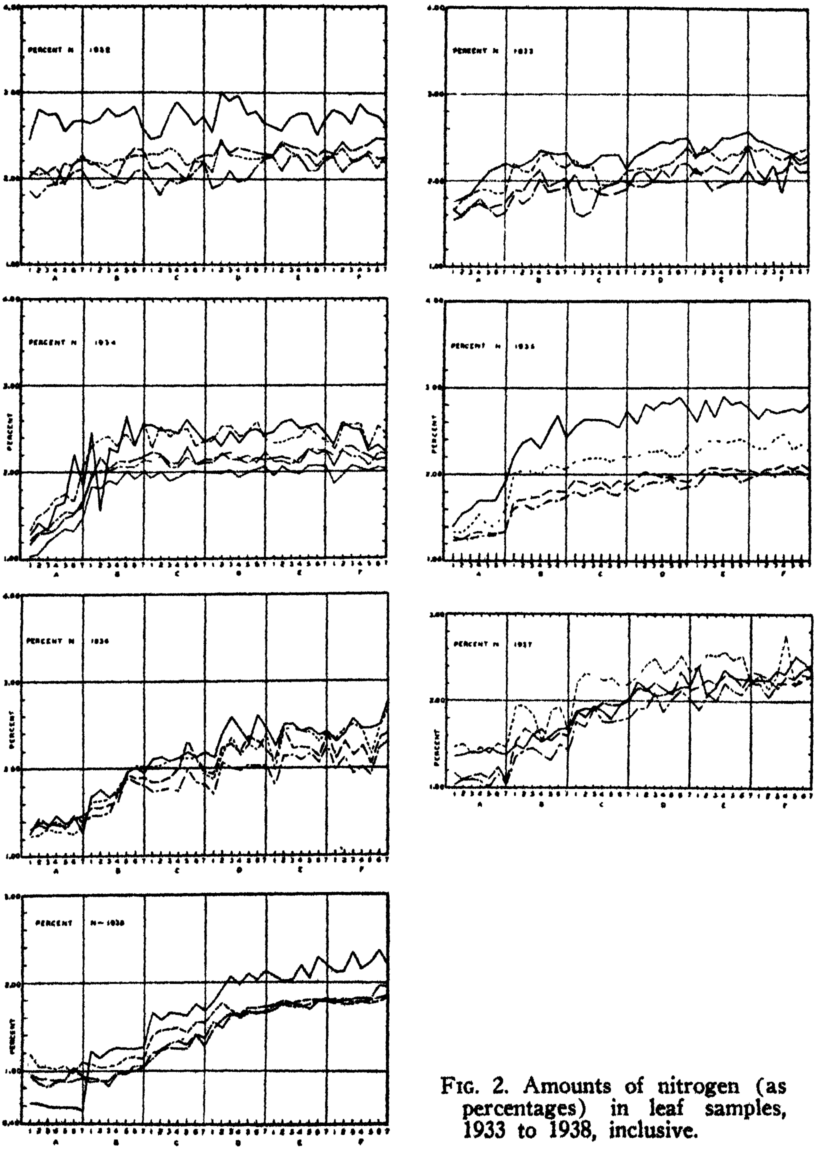

FIG. 2. Amounts of nitrogen (as percentages) in leaf samples, 1933 to 1938, inclusive.

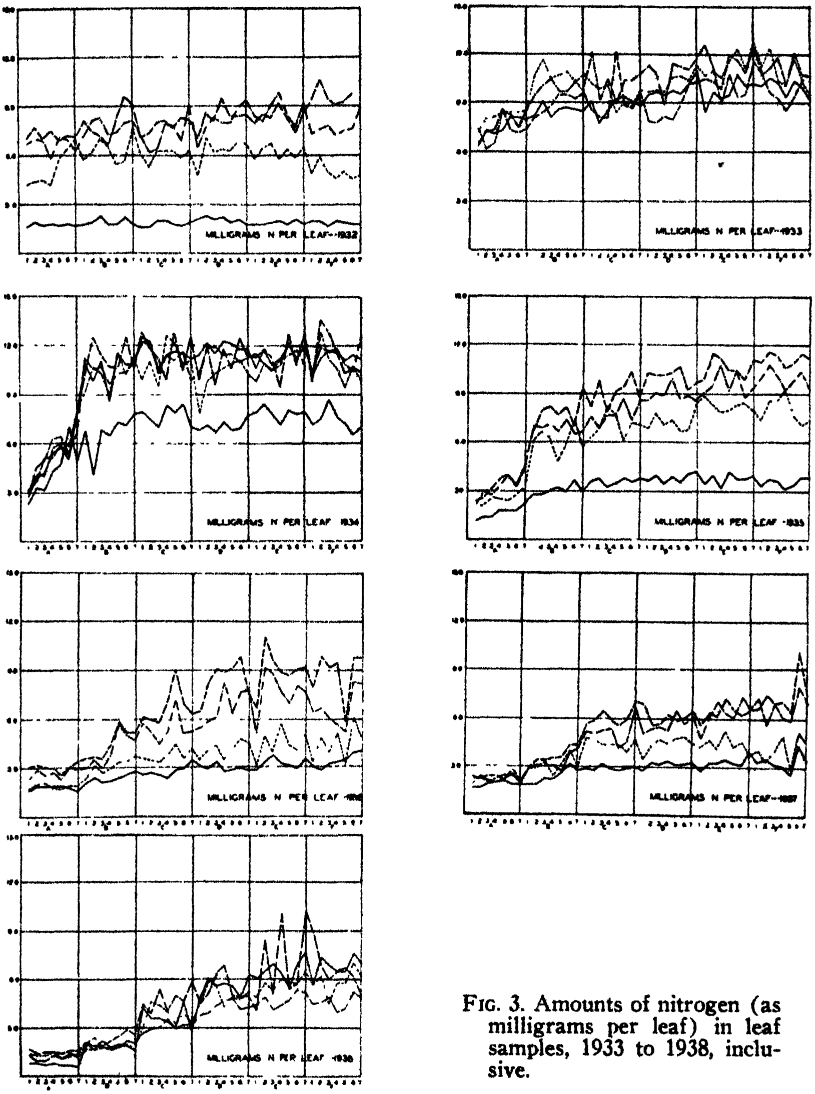

FIG. 3. Amounts of nitrogen (as milligrams per leaf) in leaf samples, 1933 to 1938, inclusive.

DISCUSSION

An examination of Fig. 1 shows that, starting with 1934, in certain sample series the leaf weights reflected the nitrogen applications; that is, the trees receiving no nitrogen (row A) had lower leaf weights than the other rows. During the subsequent years this relationship became more pronounced, so that by 1938 there was a gradual, although somewhat irregular increase in leaf weights from row A (no nitrogen) through row E (four units of nitrogen). It is apparent from an examination of this figure that the first samples taken in each year did not always show significant differences among the experimental trees as did the later samples. Further, it appears that the leaf weights increased rather regularly on all trees from the first to third samplings, and in most years the average leaf weight for the fourth sampling was less than at the time of the third sampling.

Comparing these data with the nitrogen analyses shown in Figs. 2 and 3, it is apparent that the nitrogen figures (expressed either as per cent or milligrams per leaf) also reflect the nitrogen applications in much the same way as did the leaf weights. Neither the air-dry leaf weights nor the leaf nitrogen figures show any appreciable degree of correlation with organic matter in the green manure applications. The green manure applications did, however, contain appreciable amounts of nitrogen so that from tree A-1 to A-7, for example, there was a slight, but regular increase in nitrogen applications.

Since the average air-dry leaf weights are relatively easy to secure, and the chemical analyses considerably more difficult, the question as to whether the leaf weights reflect the nitrogen applications as well as the nitrogen analyses naturally presented itself. Further, since it was obvious that there was considerable variation between the results secured on the different sampling dates, it was of considerable importance to know at what period of the growing season the greatest degree of correlation between nitrogen applications and the two "yardsticks" adopted was to be expected.

To answer these questions, correlation coefficients were calculated, first between nitrogen applications and the average air-dry leaf weights for each corresponding tree, and secondly, between nitrogen applications and leaf nitrogen analyses expressed as milligrams of the element per leaf. For each year the amounts of nitrogen applied up to that year were used to correlate with the leaf weights or nitrogen data, for example, the leaf weights and leaf nitrogen in 1937 were correlated with the amounts of nitrogen applied through 1936, and so

TABLE II—CORRELATION COEFFICIENTS BETWEEN GRAMS OF NITROGEN APPLIED AND (A) AVERAGE AIR-DRY LEAF WEIGHTS; (B) MILLIGRAMS OF NITROGEN PER LEAF ON VARIOUS SAMPLING DATES

Year	First Sampling*	Second Sampling*	Third Sampling*	Fourth Sampling*	Fifth Sampling*
			A—Average Air-Dry Leaf Weights		
1933	0.608 ±0.066	0.210 ±0.099	0.190 ±0.100	0.443 ±0.084	
1934	0.566 ±0.071	0.580 ±0.069	0.566 ±0.071	0.607 ±0.066	0.671 ±0.057
1935	0.644 ±0.061	0.777 ±0.041	0.779 ±0.041	0.822 ±0.034	—
1936	0.291 ±0.095	0.575 ±0.070	0.854 ±0.028	0.716 ±0.051	—
1937	0.225 ±0.099	0.306 ±0.094	0.721 ±0.050	0.717 ±0.051	—
1938	0.885 ±0.022	0.885 ±0.022	0.702 ±0.053†	0.767 ±0.043‡	—
			B—Milligrams of Nitrogen Per Leaf		
1933	0.833 ±0.032	0.648 ±0.060	0.643 ±0.061	0.652 ±0.060	—
1934	0.645 ±0.061	0.638 ±0.062	0.595 ±0.067	0.666 ±0.058	0.676 ±0.056
1935	0.747 ±0.046	0.797 ±0.038	0.874 ±0.024	0.890 ±0.022	—
1936	0.807 ±0.036	0.832 ±0.032	0.871 ±0.025	0.826 ±0.033	—
1937	0.838 ±0.031	0.688 ±0.055	0.863 ±0.026	0.916 ±0.016	—
1938	0.939 ±0.012	0.930 ±0.014	0.827 ±0.033†	0.933 ±0.013‡	—

*See Table I for sampling dates.
†Terminal leaves, September 26.
‡Spur leaves, September 26.

on. The correlation coefficients thus calculated are presented in Table II.

From Table II it appears that there is considerable variation in the degree of correlation between air-dry leaf weights and nitrogen applications, particularly in the first sampling. This confirms the observations made previously from a casual examination of the data in Fig. 1. The data further indicate that in general the highest degree of correlation appears to result when samples are taken from late August to early October (third or fourth samplings). Excluding the results for the first year (1933), the correlation coefficients for the last two sampling periods in all years were highly significant, ranging from 0.566 to 0.854.

The correlation between leaf nitrogen and nitrogen applications is in general considerably higher than those mentioned in the preceding paragraph between leaf weights and nitrogen applications, and much more consistent, both from year to year and from month to month. The figures presented in the second half of Table II indicate that the nitrogen analyses of leaves taken in any of the four samplings gave a reasonably accurate reflection of the nitrogen applications, although there was a slightly higher degree of correlation late in the season.

Excluding the data for the first year (1933) which were inconclusive, it may be said that the degree of correlation between air-dry leaf weights and nitrogen applications in these trees was highly significant, provided the samples were taken during the late summer, from late August to early October. Thus it may be possible for a worker not equipped to make chemical analyses to secure through measurements of air-dry leaf weights a fairly accurate picture of the nitrogen nutrition of apple trees. The chemical analyses of the leaves, however, appears to furnish a more consistently reliable reflection of nitrogen fertilization.

CONCLUSIONS

A statistical study of 1050 apple leaf samples taken from 42 trees in the period between their sixth and eleventh years, fertilized with increasing amounts of nitrogen under closely controlled conditions gave the following results:

1. Nitrogen analyses of the leaves consistently reflected the fertilizer nitrogen applications, the coefficients of correlation ranging from 0.595 ± 0.067 to 0.939 ± 0.012.

2. Air-dry leaf weights exhibited an irregular but usually high degree of correlation with fertilizer nitrogen applications, the coefficients of correlation ranging from 0.190 ± 0.100 to 0.885 ± 0.022.

3. The results obtained during the first year of this study were irregular, but during the subsequent years the air-dry leaf weights correlated best with fertilizer nitrogen applications late in the growing season, from late August to early October, at which time r varied from 0.566 to 0.854.

4. Leaf nitrogen analyses showed a rather consistent degree of correlation with fertilizer nitrogen applications throughout the growing season, with a slightly higher degree of correlation late in the summer. The coefficients of correlation varied from 0.595 to 0.939,

and were higher than those found between air-dry leaf weights and nitrogen fertilization.

5. There was no apparent relation between green manure applications and either air-dry leaf weights or leaf nitrogen analyses.

The Stimulatory Effect of One Lot of Apples on Another in Storage

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Abstract

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THE magnitude of the stimulatory effect of one lot of apples on another may vary from no effect to a very considerable one. In some experiments as much as 50 per cent of the storage life of a lot of apples was lost because of exposure to the emanations of other apples. The stimulatory emanation is presumably ethylene but was not identified as such.

The magnitude of this stimulatory effect depends upon:

1. *The maturity of the lot being "stimulated":*—No stimulation was noted from the emanations of ripe apples after the climacteric rise was well under way. Varieties like Rhode Island Greening that are most likely to be picked well before the climacteric rise are the ones most likely to be affected by other lots of fruit.
2. *The maturity of the fruit supplying the emanations:* — Post-climacteric apples are more potent sources of this stimulation effect than pre-climacteric.
3. *The temperature of the storage:*—Significant effects were quickly apparent and in general more striking at higher temperatures, although effects were noted at cold storage temperatures.
4. *The number of apples supplying the emanations:*—As few as 1 per cent of the total number of apples are required to supply the stimulating emanations to get a significant effect in ripening. Large numbers of ripe apples may have no more effect or possibly even less effect than a comparatively few ripe apples.
5. *The composition of the atmosphere:*—Stimulation effects were commonly noted in ordinary air storage but no such effect could be observed in controlled atmosphere storage.
6. *The variety of the lot supplying emanations:*—Some varieties seemed to have a more marked stimulating influence on pre-climacteric apples than others.

A number of absorbents were tested in trying to "air condition" the storage atmosphere to remove the stimulating emanations. Among the ineffective absorbents were activated charcoal, sulphuric acid, activated sulphuric acid, sodium bisulfite, certain oils and water. Among those which had some beneficial effects were sodium hydroxide solution, certain other oils, morpholine, and alkaline potassium permanganate. The only really effective absorbent was bromine gas adsorbed on the surfaces of activated charcoal.

Preliminary Tests With Uramon in Foliage Sprays as a Means of Regulating the Nitrogen Supply of Apple Trees[1]

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THE possibility that nitrogen, as well as other elements (1), may be assimilated through the leaves in appreciable quantities suggests its application in the foliage sprays as a means of controlling the supply of nitrogen to fruit trees. The observations and the data from these studies are presented as a report of progress and should be considered of a preliminary and exploratory nature.

METHODS

Two experimental plats were located in mature McIntosh orchards in western New York during the season of 1942. One of the McIntosh orchards was mulched, was of good vigor, and bore a heavy crop of fruit, while the other had received no fertilizer for the past 7 years and bore a light crop of fruit. Both orchards were in sod. Five trees were sprayed with each treatment. Between each of the sprayed plats, there was one tree with a soil treatment of 10 pounds of ammonium sulphate and one tree receiving no fertilizer.

A third experimental plat of Cortland and Rome Beauty was located in the Hudson Valley. The trees were medium in size and had never received fertilizer; although the orchard was not cultivated, there was practically no sod. Single 10-tree rows of alternating Cortland and Rome Beauty were used for each treatment and for the untreated check.

Although the season was 2 weeks earlier than usual, temperature and rainfall were such as to promote normal growth of the trees.

Nitrogen carriers were applied to the foliage with wettable sulfur, lime, and arsenate of lead, each at 3–100 (3 pounds to 100 gallons of water). Chilean nitrate, synthetic sodium nitrate, potassium nitrate, ammonium sulphate, and Uramon (urea) were tested. The nitrates were used at 5–100 and the other materials were applied on a comparable nitrogen basis. Uramon was also tested at 5– and 10–100. The trees were sprayed from the outside only, with an average application which amounted to about 10 to 15 gallons for a mature McIntosh tree capable of bearing 20 to 30 bushels of fruit. The sprays were applied in the pink stage, at petal-fall, 14 days after petal-fall, and 30 days after petal-fall. Terminal growth was about completed at the time the final spray was applied.

FOLIAGE INJURY

The sprays containing nitrate materials, at 5–100, caused considerable foliage injury, possibly due to the reaction with the arsenate of lead even though lime was used at 3–100. The Chilean nitrate was the most injurious of the nitrates and the potassium nitrate the least. The McIntosh foliage was more severely injured than that of the Rome Beauty or Cortland. Potassium nitrate caused only slight injury to Rome Beauty and Cortland foliage.

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[1] The authors are indebted to R. C. Collison for valuable suggestions.

Ammonium sulphate, at 5–100, with lime 3–100, did not cause injury to any of these varieties. Slight injury resulted when it was used at 8–100 on McIntosh.

Uramon, 5–100, with lime 1–100, caused no injury to McIntosh, but severe burning resulted at a concentration of 10–100. Uramon, 5–100, with lime 3–100, caused no injury to Rome or Cortland foliage, slight injury at 10–100, and severe injury at 15 or 20–100, even with only one application.

Tests on Ben Davis indicate that if injury is to be avoided, sodium nitrate and ammonium sulphate must be used with an equal amount of lime when arsenate of lead is added. Uramon did not cause injury at concentrations from 2– to 5–100 with or without lime.

It may be of interest to note that none of these materials caused injury to cherries at concentrations of 5–100 when applied with an insoluble copper, lime, and lead arsenate spray or to peaches when applied in a zinc sulphate-lime spray. Uramon was used as high as 10–100 without injury.

RESPONSE TO TREATMENT

The nitrate materials seemed to increase the intensity of the leaf color, but injury to the foliage precludes detailed consideration of them at present. Ammonium sulphate as might be expected did not noticeably increase leaf color when used in combination with lime and arsenate of lead. Uramon, 2–100, seemed somewhat to increase foliage color early in the season on all varieties, but gradually the effect disappeared except on trees with a light load of fruit. Uramon, 5–100, seemed about the right concentration for trees of average vigor. Here too, however, the increased intensity in color of the foliage of the trees receiving the pink, petal-fall, and 14-day applications had disappeared well before harvest, except on trees with a light crop. The foliage that received an additional application of Uramon, 5–100, 30 days after bloom remained appreciably greener until leaf-fall than leaves on untreated check trees. The most noticeable increase in color resulted from the 30-day application. An evaluation of each of the early sprays was not made. When growth was well advanced, increased leaf color was noted in as short a period as 5 to 10 days following single applications of Uramon, 5– or 10–100. The foliage on treated trees, with the exception of those receiving a soil application, began to lose color by the middle of July. Fruit color was not affected by any of the spray treatments; but where 10 pounds of ammonium sulphate were applied to the soil, fruits were noticeably greener than where no fertilizer was applied. Conditions just previous to harvest were very favorable for the development of red color.

LEAF ANALYSIS

Results of nitrogen determinations of leaf tissue taken from the experimental plats the middle of July and at the end of September are given in Table I. Leaves from the vigorous McIntosh orchard with the heavy crop of fruit which were sprayed with Uramon, 2–100, did not have a nitrogen content appreciably above that of the trees receiving no fertilizer, but leaves from the less vigorous McIntosh block with a light crop of fruit did have a significant increase. The foliage sprayed with Uramon, 5–100, had a nitrogen content of about 2 per cent early in July with a marked decline at harvest. The nitrogen content of leaves from the trees with the soil application of ammonium sulphate was only slightly higher than that of those sprayed with Uramon, 5–100, even though the fruit had poorer color when harvested. There is a suggestion that the nitrogen content of leaves sprayed with Uramon was increased by the addition of manganese sulphate (Tecmangam).

DISCUSSION

From the studies here reported, it is suggested that nonprotein organic nitrogen (urea) may be applied to apple trees without injury with foliage sprays now designed for disease and insect control. This suggests the possibility of controlling the nutritional status of the tree more closely than might be accomplished by soil application, and of applying fertilizers in the way as supplementary to soil treatments. For example, it is possible to apply nitrogen in the fore part of the season so as to have it available for growth and fruit set, and yet to have a depletion of nitrogen in the fall so as not to interfere with good coloring of fruit. The value of such a practice might be accentuated during periods of low rainfall or in dry areas.

It is of interest that such small differences in the nitrogen content of the leaf as shown in Table I can be correlated with relatively large differences in the greenness of the foliage. In this connection it was observed that the rate of growth of a tree may determine the increase in color intensity from a nitrogen application and this may prove a factor in concentration and number of sprays required for desired results. When the trees are growing rapidly or when the foliage is completely mature, color changes in the foliage need not be expected. Temperature, fruit species, and soil all have a bearing upon the results secured.

The fact that the nitrogen carriers used are very soluble might indicate that they were washed to the ground and that the nitrogen entered through the roots. This is a possibility, but the amount must of necessity have been small since only a small amount of nitrogen was contained in any one application (½ to ¾ pound of Uramon to a 17-year-old tree) and the orchards were in sod. Unpublished data indicate that nitrogen enters through the under sides of the leaves, a fact that was not taken into consideration when the trees in these tests were sprayed.

It is possible that special applications of the nitrate materials, which caused injury when tested with arsenate of lead, might be made safely

TABLE I—EFFECT OF FOLIAGE APPLICATIONS OF URAMON ON THE NITROGEN CONTENT OF McINTOSH APPLE LEAVES*

Treatment**	Number Sprays Applied***	Per Cent Nitrogen (Dry Weight Basis Individual Trees)			
		Lewis Orchard†		Smart Orchard‡	
		Jul 15	Sep 30	Jul 15	Sep 30
Unfertilized	None	1.79 1.82 1.80 1.81 1.84	1.50 1.49 1.48 1.58 1.52	1.69 1.77 1.70 — —	1.50 1.45 1.46 — —
Uramon 2-100	3	1.86 1.87 1.88 —	1.54 1.55 1.40 —	1.88 1.88 1.98 1.96	1.47 1.47 1.35 1.52
Uramon 2-100	4	1.80 1.93	1.42 1.50	— —	— —
Uramon 5-100	3	2.08 1.89 2.02 —	1.50 1.55 1.60 —	2.06 2.05 2.00 2.07	1.57 1.49 1.60 1.47
Uramon 5-100	4	2.18 2.13	1.61 1.68	— —	— —
Uramon 2-100 and Tecmangam§ 2-100	3	1.92 1.92	1.51 1.50	— —	— —
	4	2.03 2.00	1.64 1.60	— —	— —
Soil treatment Ammonium sulphate 10 pounds per tree	None	2.20 2.20 2.17 2.23 2.18	1.70 1.74 1.65 1.71 1.77	2.19 2.30 2.46 2.27 —	— 1.80 1.77 1.71 —

*Each tree was sampled by two people, from the ground. 200 leaves were taken from the middle of the terminals of each tree.

**All sprays were applied in combination with wettable sulfur, arsenate of lead, and lime, each 3-100.

***Applications were made at pink (May 2), petal-fall (May 11), 14 days after petal-fall (May 25), and 30 days after petal-fall (June 10). The first three sprays were applied to the five trees of each plat and the fourth spray to two trees only of a given plat.

†The Lewis orchard was in good commercial vigor with uniform trees bearing an average of 20 bushels per tree. Trees were in sod and mulch.

‡The Smart orchard was in low vigor and bore only a light crop. Trees were in sod and had not received any fertilizer for 7 years.

§The Tecmangam contained approximately 65 per cent manganese sulphate and 10 per cent ammonium sulphate.

if the arsenical were omitted. Wettable sulfurs and an available supply of organic nitrogen add to the possibilities of introducing nitrogen into the spray mixture. Such a practice would have been considered impossible a few years ago with the materials then in use, if for no other reason than the danger from arsenical injury.

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Effect of Ringing the Stem on Photosynthesis, Transpiration and Respiration of Pecan Leaves

By A. J. Loustalot, *U. S. Department of Agriculture, Brownwood, Tex.*

CERTAIN horticultural practices and experiments involve ringing the trunks or stems of plants. Such treatment is known to bring about physiological and chemical changes in the tissues above and below the wound. In order to better evaluate and interpret data and observations obtained from experiments where ringing is done, more specific knowledge is needed of the effects of this treatment upon the metabolic activity of the plant. Heinicke (3) has shown that ringing the stems of the apple rapidly and markedly depresses the assimilation of CO_2 in the leaves above the wound. The experiments herein reported were designed to determine what effects ringing the branches of the pecan tree would have on the rates of photosynthesis, transpiration, and respiration of the leaves.

Methods

The apparatus used and the procedure followed to determine the carbon dioxide differences were similar to those described by Heinicke and Hoffman (6). The chambers for CO_2 assimilation and respiration studies were similar to those described by Heinicke (4) but adapted for use with pecan leaves by Loustalot and Hamilton (7). The water transpired was determined by passing the air through a dehydrating agent before it reached the CO_2 absorption towers and determining the increase in weight (5).

Procedure

Two experiments were conducted with normal mature leaves on a 12-year-old pecan tree of the variety Western growing near the laboratory of the United States Department of Agriculture Pecan Field Station at Brownwood, Texas. In each experiment two pairs of comparable leaflets with similar exposure and position on the tree were selected. One pair was designated as check and the other as test leaflets. The photosynthetic and transpiration rates of the two pairs of leaflets were determined for a period of 5 or 6 days prior to ringing the branches carrying the test leaflets, thus establishing the relationship of these functions in the two pairs before ringing. After this calibration period a ring of bark about ¼ inch wide was removed from the branch supporting the test leaves. The wounds were immediately protected from drying by covering with melted grafting wax. Measurements of CO_2 assimilation and transpiration were made for a period of 5 or 6 days following the ringing treatment. Subsequent determinations were made on two successive days, beginning 50 days after ringing in the case of the first experiment and 38 days after ringing in the second experiment, to ascertain the persistence of the effects of ringing.

Usually two determinations of photosynthesis and transpiration were made daily for 3-hour periods both in the morning and in the afternoon. The morning determinations usually began at 8:45 a.m. and terminated at 11:45 a.m. The afternoon determinations began at 12:00 noon, and ended at 3:00 p.m. In the second experiment respiration determinations were made in the afternoons from 3:15 to 6:15 p.m. In these determinations the leaf-cups with the leaves attached were covered with bags made of several thicknesses of black cloth which completely excluded the light. The temperature inside the bags varied very little from that of the outside air, since the leaves were located on the east side of the tree and were in full shade during the time the respiration measurements were made.

Experiment 1 was started on June 10th and the branch bearing the test leaflets was ringed at 3:00 p.m. on June 15th. Experiment 2 was started on June 23 and the test branch was ringed on June 29 at 8:30 a.m. The data for the three experiments are presented graphically in Figs. 1, 2, and 3.

RESULTS

In both experiments a substantial reduction in CO_2 assimilation and transpiration occurred in leaflets on ringed branches within 1 to 2 days after the ringing was done. In experiment 1 a reduction of 60 per cent in photosynthesis occurred during the second afternoon following ringing and this relative position was maintained during the succeeding five days (Fig. 1). The reduction in photosynthesis in leaflets on

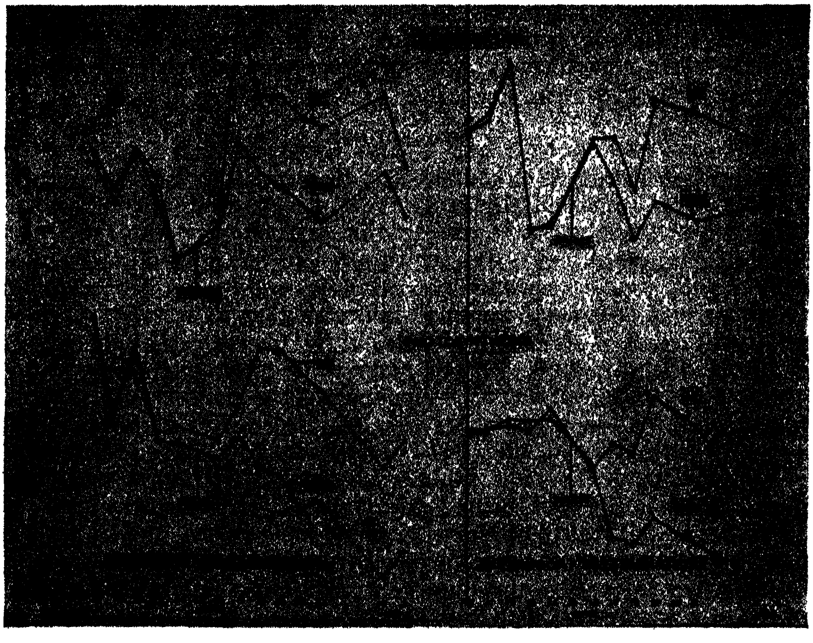

FIG. 1. Carbon dioxide assimilated and water transpired by pecan leaves on ringed and unringed branches, experiment 1. (Mgs CO_2 and gms H_2O per hr/100 Cm^2).

ringed branches for the morning periods was somewhat less than that for the afternoon periods but the relationship otherwise was similar.

A reduction of about 60 per cent in the rate of transpiration of test leaflets occurred during the afternoon of the third day after the branches were ringed and a maximum reduction of 70 per cent was attained on the afternoon of the sixth day. Subsequent determinations on August 4 and 5 (50 days after ringing) showed a further depression in the rate of photosynthesis (75 to 80 per cent below normal) while transpiration showed a tendency toward recovery, the rate then being 40 to 50 per cent lower than that of the normal leaflets.

In the second experiment a 25 per cent reduction in photosynthesis of test leaflets occurred during the afternoon of the day following the ringing treatment, and by the afternoon of the third day the reduction amounted to 59 per cent (Fig. 2). As in the first experiment the reduction in CO_2 assimilation was somewhat lower for the morning determinations than that for the afternoon determinations, but at the end of the fourth day following ringing the percentage reduction for both morning and afternoon periods was about the same. Transpiration in the test leaflets was affected in about the same way as CO_2 assimilation for both the morning and the afternoon periods. Subsequent determinations on August 6 and 7 (38 days after ringing) showed a further depression in the ability of the leaflets on ringed branches to

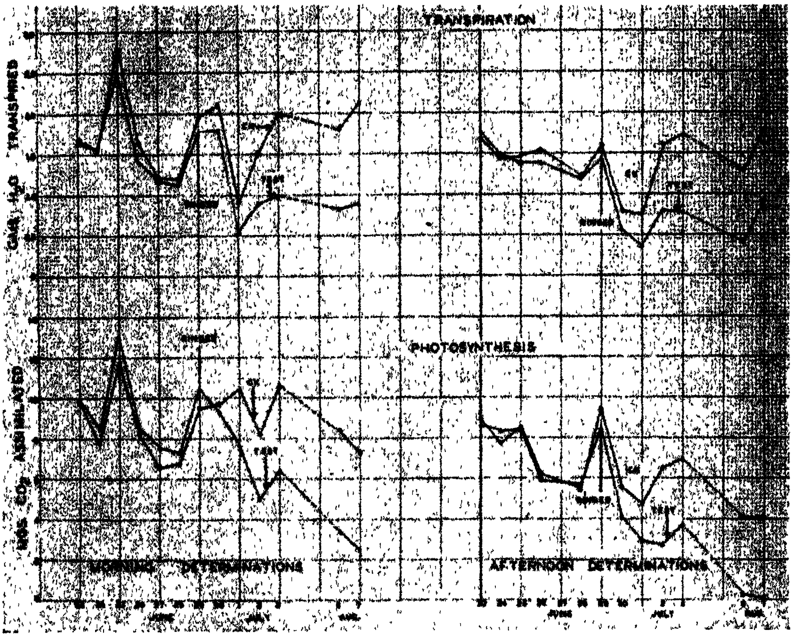

FIG. 2. Carbon dioxide assimilated and water transpired by pecan leaves on ringed and unringed branches, experiment 2. (Mgs CO_2 and gms H_2O per hr/100 Cm^2).

assimilate CO_2, the rate of assimilation for the morning periods being 62 to 68 per cent below normal while for the afternoon periods it was 93 to 97 per cent below normal. The transpiration rates of the test leaflets for the morning determinations of these two days was 51 to 56 per cent below normal and for the afternoon periods it was 47 to 66 per cent below normal.

The data for the respiration determinations show a 10 per cent increase in the evolution of CO_2 from the test leaflets during the afternoon of the day on which the branch was ringed (Fig. 3). In the next 4 days the rate of respiration increased to 34 per cent above the normal rate. Subsequent determinations on August 6 and 7 (38 and 39 days after ringing) showed a further increase in respiration to 54 and 42 per cent, respectively, above the normal rate.

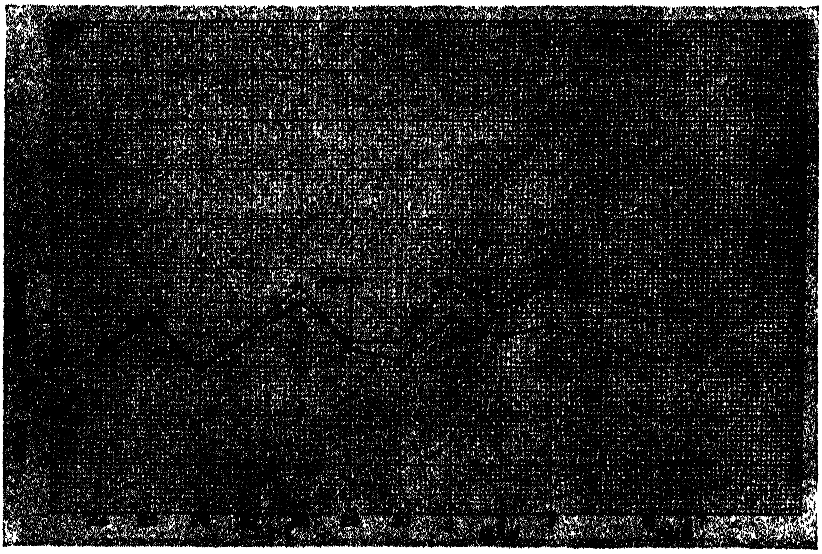

FIG. 3. Respiration of pecan leaves on ringed and unringed branches. (Mgs CO_2 per hr/100 Cm^2).

These data suggest that the depression in apparent photosynthesis of leaves on ringed branches is due, at least in part, to the increased evolution of CO_2 which would partly mark photosynthesis activity; but it is also apparent that this does not account for the entire amount of reduction in the CO_2 assimilation in the leaves.

DISCUSSION

It is evident from the data presented in this paper and in others (3) that ringing of the stem brings about a substantial reduction in apparent photosynthesis and transpiration of the leaves above the wound, and it is also apparent that this depression continues over a long period of time. Although no determinations were made on pecan leaflets after August 7 it is not unreasonable to suppose that the deleterious effects of the ringing continued until leaf fall. There was no apparent difference in the external appearance of leaves on ringed and unringed branches, but the leaves on ringed branches abscised about the middle of September which is abnormally early for pecan leaves to drop. The ringed branches were considerably thicker above the ring than they were below and much callus formation was present on the upper side of the wound. The fact that the abscission layer had formed so early in the leaves is an indication that active metabolism in the branches was slowed down as a result of the ringing. This is in agreement with the findings of Heinicke (2) in studies of the formation of the abscission layer and the factors causing it.

The reduced rate of apparent photosynthesis of leaves on ringed branches may be the result of one or more of several factors. It is fairly well established that an accumulation of the products of photosynthesis will cause a retardation in the assimilation of CO_2. Ringing is known to bring about such accumulation. It has been demonstrated by Curtis (1) and others that the phloem is the probable tissue through which minerals and elaborated foods are normally translocated. Therefore, it might be expected that the removal of a ring of bark from the stem would interfere with the movement of mineral elements into the leaves above the ring and thereby limit the rate of the photo-chemical reaction. Another factor to be considered is the possible deficit of water in the leaves as a result of the ringing, since the data indicate a reduced rate of transpiration by leaves on ringed branches, although there was no outward indication of wilting. However, it is probable that the increased rate of respiration or the accumulation of photosynthate might produce sufficient chemical changes in the guard cells to cause the stomates to be partly or completely closed, which could cause a reduction in the transpiration rate.

With the reduction in the rate of photosynthesis the net amount of carbohydrates produced by leaves on ringed branches is considerably smaller than that produced by leaves on unringed branches, and therefore the amount of elaborated food available for new leaf and shoot growth and for the development of nuts is substantially reduced.

In evaluating the results of studies concerning the relation of foliage to filling of pecan nuts on ringed branches, it may be necessary to discount some of the values indicated or conclusions drawn. In such experiments, a given number of leaves is usually indicated as being necessary for the proper filling of a nut. On the basis of the data obtained in the present experiments, it is obvious that, with other things being equal, fewer leaves on unringed branches will be required to fill a nut than where the leaves are functioning at one-half to three-fourths of their capacity on ringed branches. In practice, the fact that more materials could be translocated from the unringed than from the ringed branches would have to be considered in making comparisons of the number of leaves required for proper fruit development.

SUMMARY

Experiments were conducted to determine the effects of ringing pecan branches on the rates of photosynthesis, transpiration, and

respiration in leaves above the ring. The data clearly indicate a substantial reduction in the rates of photosynthesis and transpiration one to two days following the treatment. The extent of reduction in both processes varied and was as low as 50 to 75 per cent below that of the normal rate. Determinations made 50 days after ringing (experiment 1) and 38 days after ringing (experiment 2) showed that the deleterious effects of ringing had increased in the case of photosynthesis, while the effects on transpiration were about the same or less than those recorded 2 or 3 days after the branches were ringed.

The rate of respiration of leaves on ringed branches was accelerated as a result of the treatment. There was a 10 per cent increase in the evolution of CO_2 from the test leaflets during the afternoon of the day on which the branch was ringed, and in the next 4 days the rate increased to 34 per cent. Determinations made 38 and 39 days after ringing showed a further increase to 54 and 42 per cent respectively above the normal respiration rate.

The leaves on ringed branches abscised from 1 to 2 months earlier than those on unringed branches, although the leaves on ringed and unringed branches had the same appearance.

In the light of these and similar data (3) it may be necessary to re-evaluate some of the conclusions drawn from studies concerning leaf-fruit relationships which involve ringing experiments.

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The Carbon Dioxide Intake of Apple Leaves as Affected by Reducing the Available Soil Water to Different Levels[1]

By D. F. ALLMENDINGER, A. L. KENWORTHY, and E. L. OVERHOLSER, *State College of Washington, Pullman, Wash.*

THE extent to which a plant may reduce available soil moisture without being adversely affected has been extensively investigated. Lewis, Work, and Aldrich (7) reported that the growth of fruit of pears was decreased when the soil moisture in the major portion of the root zone was reduced below 70 per cent of the available water.

Claypool (1) found that soil moisture, between the wilting point and field capacity, did not appear to be uniformly available to apple trees. Soil moisture became progressively more of a factor resulting in stomata closure of apple leaves, and a decrease in fruit size as the available soil moisture was reduced to zero, as compared with trees receiving sufficient water.

Heinicke and Childers (3) reported that a gradual drying-out of the soil was accompanied by a reduction in the rates of transpiration and photosynthesis. The data indicate that the soil moisture was near the wilting point before the reduction in carbon dioxide intake occurred.

Schneider and Childers (9) reported that with apple trees, a marked reduction in apparent photosynthetic activity and in transpiration, and an increase in respiration occurred before wilting was evident.

Hendrickson and Veihmeyer (5) found that with peaches, pears, and prunes, the soil moisture was readily available between the moisture equivalent and the permanent wilting percentage. These same authors (6) have also shown that growth of apples and pears was not retarded so long as the permanent wilting percentage of the soil was not reached.

This investigation was an attempt to determine the influence of the available soil moisture upon the apparent photosynthetic activity of apple leaves and also the influence of decreasing the proportions of available soil moisture utilized before watering to replenish the moisture to field capacity of the soil upon the ultimate capacity of the leaves to absorb carbon dioxide. The intake of carbon dioxide by the leaves was determined and coordinated with the prevailing soil moisture and with previous treatment of the trees with regard to frequency of watering. These determinations were made over a period of one month beginning about three and one-half months after the trees were planted and maintained with different soil-moisture relations.

METHODS AND MATERIALS

Soil:—The soil used consisted of 6 parts Palouse sod, which had been dried, ground, and screened to ¼ inch; 3 parts of clean fine river sand; and 1 part of acid peat moss by volume. This mixture showed little shrinkage in volume as the soil dried. The field capacity as deter-

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mined by the suction method of Bouyoucos (2) was 37 per cent. The wilting point of the soil as determined by wilting sunflowers was 7 per cent. This made approximately 30 per cent moisture available for plant utilization.

Trees, Containers, and Moisture Relations:—One-year-old, 3- to 4-foot Winesap nursery trees, which had been propagated by whip grafts on standard understocks, were planted on January 11, 1941 in 50-pound berry cans in the greenhouse. Each can contained an equivalent of 49 pounds of oven-dry soil, which at planting time contained 10.5 per cent moisture. The trees were pruned to 14 inches above the graft union when planted.

Between February 19 and February 21, two tensiometers, a modifications of the tensiometers described by Richards (8), were installed in each container. A sample of the soil was used in the laboratory for the calibration of the tensiometers by the drying-out method. After calibration, the available soil moisture range maintained for the different lots of trees was as follows: (a) one-fifth of the available moisture utilized before each subsequent watering; (b) two-fifths utilized before watering; (c) three-fifths utilized before watering; (d) four-fifths utilized before watering; and (e) all of the available water utilized before watering. Readings of the tensiometers were made at 5:00 p.m. daily, and the trees watered as necessary. Sufficient water was applied to each plant at the time of watering to bring the soil mass to field capacity. The tension exerted when the soil was below approximately 9 per cent moisture was too great to be measured accurately by the tensiometers; therefore the watering time for the trees utilizing all of the available soil moisture before watering, was determined by the wilting of the leaves.

Determination of Carbon Dioxide Intake:—The photosynthetic apparatus used was a modification of that described by Heinicke and Hoffman (4). It consisted of 18 absorption towers, 15 utilized for the determination of the carbon dioxide content of the air that had passed over the leaves, and three for air checks.

Air was drawn over 9 to 13 leaves on each terminal enclosed in a cylindrical cellophane envelope for the 4-hour period of each determination. By use of a system of by-passes and manometers, approximately two-ninths of the total air passing over the leaves was bubbled through the absorbing solution of potassium hydroxide. The aliquot of air drawn through each by-pass, and through each absorption tower, was measured with a wet test meter three times during each 4-hour determination.

Leaf area measurements were made three times during the 4 weeks of the experiment and necessary compensations made for growth of the terminal leaves.

Three determinations were made each week for 4 weeks, starting approximately 3½ months after the trees were planted.

PRESENTATION OF DATA AND DISCUSSION

The determinations of carbon dioxide intake were started between 8 and 10 o'clock in the morning and ran for 4 hours. The light intensity varied from an average of 2140 to 5140 foot candles. The carbon dioxide content of the air as determined by three readings during each determination, varied from 0.49 to 0.56 milligrams per liter of air. The relative humidity and temperature, as determined by three readings during each determination, varied from 38 to 49 per cent, and from 69 to 81 degrees F.

From an analysis of these and other data, it was found that these variations were not of such magnitude as to materially influence the carbon dioxide intake of the leaves.

Previous experiments (unpublished) have shown that variations in light intensity, so long as the light intensity is above 1200 to 1400 foot candles, have no measurable influence upon the carbon dioxide intake of apple leaves grown under comparable conditions.

Watering Dates:—The dates of watering during the period of the photosynthetic determinations are shown in Table I.

TABLE I—DATES OF WATERING DURING PERIOD OF PHOTOSYNTHETIC DETERMINATIONS

Moisture Ranges	Tree	Watering Dates
Utilizing one-fifth of available H_2O before watering	6	April 23, 24, 25, 26, 27, 28, 29, 30, May 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18
	22	April 22, 23, 24, 25, 26, 27, 28, 29, 30, May 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
	27	April 21, 22, 23, 24, 25, 26, 28, 29, 30, May 2, 3, 5, 6, 8, 10, 11, 13, 15, 17, 18
Utilizing two-fifths of available water	18	April 22, 25, 28, May 1, 4, 8, 11, 15, 18
	7	April 22, 25, 28, 30, May 2, 5, 8, 10. 13, 16
	2	April 22, 24, 27, 29, May 1, 3, 6, 8, 10, 12, 15, 18
Utilizing three-fifths of available water	8	April 23, 27, 30, May 5, 9, 12, 15
	14	April 22, 26, 30, May 2, 5, 8, 10, 13, 16
	3	April 20, 24, 27, 30, May 5, 9, 12, 16
Utilizing four-fifths of available water	15	April 25, May 3, 12
	30	April 21, 28, May 3, 9, 17
	5	April 20, 27. May 4, 12
Utilizing all of available water	26	April 26
	1	May 8
	4	May 7

These data indicate that the plants that utilized one-fifth of the available water before watering, were watered approximately twice as frequently as those that utilized two-fifths, and approximately three times as frequently as those that reduced the soil moisture to three-fifths of field capacity before watering. Since the field capacity was restored with each watering, all of the trees in these three plots received approximately the same amount of water during the experiment.

With plants that utilized four-fifths, and with plants that utilized all of the available water, however, the frequency of watering was reduced to such an extent that only approximately sixteen/twenty-seconds and five/twenty-seconds as much water was used respectively as by the trees of the other three plots.

Tree Growth:—The trees that utilized one-fifth, two-fifths, and three-fifths of the available soil moisture before watering to restore field capacity, produced an average total terminal growth of 259 centimeters, 230 centimeters, and 240 centimeters respectively. It is questionable if these differences can be attributed to differences in frequency of watering. With the plants that removed four-fifths of the available soil moisture, however, the average total terminal growth was 191 centimeters, indicating that there was an actual reduction in growth of these plants possibly related to the available soil moisture supply. The trees that reduced the soil moisture to the wilting point had an average total terminal growth of only 93 centimeters, indicating that the reduction of soil moisture to the wilting point seriously reduced the growth.

It is apparent from these data that a reduction in growth, as measured by terminal elongation, occurred when more than three-fifths of the available soil moisture had been removed.

Per Cent Moisture and Carbon Dioxide Intake:—The per cent moisture in the soil at the time the photosynthetic determinations were made is given in Table II. As has been previously stated, the soil moisture, when 9 per cent or below, should be considered as only approximate as the accuracy of the tensiometers was reduced at this low moisture content.

TABLE II—PER CENT MOISTURE IN SOIL ON DAYS OF PHOTOSYNTHETIC DETERMINATIONS

Tree Number	Date											
	Apr 23	Apr 25	Apr 27	Apr 30	May 2	May 4	May 7	May 9	May 11	May 14	May 16	May 18
Plants Utilizing One-Fifth of Available Water Before Watering												
6	36.0	30.0	31.5	31.0	35.1	31.5	32.0	31.0	31.0	29.0	32.0	31.5
22	32.0	30.0	30.0	30.0	30.5	31.5	32.0	32.5	32.5	30.0	28.0	35.0
27	32.5	33.0	32.5	32.0	30.0	33.0	33.0	32.5	32.0	33.5	32.0	35.0
Plants Utilizing Two-Fifths of Available Water Before Watering												
18	32.5	26.0	29.5	29.5	31.0	28.5	27.5	32.5	25.5	30.0	31.0	28.0
7	32.0	34.0	30.0	27.5	28.5	29.5	29.5	31.5	32.0	31.5	24.0	30.0
2	36.0	32.0	22.0	30.5	31.5	31.0	31.0	31.0	31.5	29.5	31.0	25.0
Plants Utilizing Three-Fifths of Available Water Before Watering												
8	20.0	29.0	18.5	20.0	30.0	21.5	28.0	16.5	23.0	27.0	30.5	26.0
14	31.5	27.0	31.0	19.5	30.0	23.5	29.5	25.0	30.5	14.5	27.5	19.5
3	22.5	30.5	22.0	20.5	28.5	21.5	28.5	17.5	28.0	29.5	21.5	30.0
Plants Utilizing Four-Fifths of Available Water Before Watering												
15	19.0	11.5	30.0	22.5	15.5	30.5	27.0	20.0	13.5	35.0	29.5	21.0
30	28.5	23.0	17.5	24.0	16.5	17.5	23.5	15.0	28.5	12.5	12.0	31.0
5	26.5	20.0	14.0	22.5	19.5	13.5	28.0	22.5	14.5	30.0	26.5	21.0
Plants Utilizing All of Available Water Before Watering												
26	12.0	10.0	34.5	30.5	24.5	19.0	15.0	13.0	12.5	10.0	10.0	9.0
1	27.5	22.0	17.5	13.0	11.5	10.5	9.5	35.5	31.0	25.0	21.0	18.0
4	11.5	10.5	9.5	9.0	9.0	8.0	8.0	35.0	27.0	22.0	18.5	15.0

In some instances the carbon dioxide intake determinations were made when the moisture content of the soil was below the point at which water should have been added. Since the tensiometers were read, and water applied only in the evening, and carbon dioxide determinations were made in the morning, it was possible for a plant to reduce the moisture content below the watering level between the time of the tensiometer readings and the time the carbon dioxide intake determinations were made.

The carbon dioxide intake of the leaves is shown in Table III.

TABLE III—CARBON DIOXIDE INTAKE OF APPLE LEAVES (MGS/HR/DM^2)

Tree Number	Date												Tree Average	Plot Average
	Apr 23	Apr 25	Apr 27	Apr 30	May 2	May 4	May 7	May 9	May 11	May 14	May 16	May 18		
	Plants Utilizing One-Fifth of Available Water Before Watering													
6	13.5	15.0	13.7	13.2	11.9	10 6	9.4	14.2	14.1	11.6	10.7	13.3	12.6	—
22	13.6	15.0	13.8	13.2	11.9	9.7	8.7	10.5	10.5	—	8.1	11.0	11.4	—
27	11.4	15.0	14.2	15.0	13.3	10.8	11.5	14.7	15.8	11.8	—	14.0	13.4	12.5
	Plants Utilizing Two-Fifths of Available Water Before Watering													
18	16.5	18.1	13.6	—	11.4	--	9.4	13.3	13.6	—	11.1	13.9	13.4	—
7	14.2	14.7	13.4	13.2	12.0	9.6	9.2	11.8	12.3	12.8	10.3	14.2	12.3	—
2	12.5	15.2	12.4	13.8	12.0	10.2	8.8	12.5	16.9	10.8	9.7	13.2	12.3	12.7
	Plants Utilizing Three-Fifths of Available Water Before Watering													
8	11.0	15.4	12.5	12.8	11.2	9.5	9.0	11.7	12.3	10.0	10.3	11.9	11.5	—
14	13.4	16.5	13.8	15.1	12.8	9.7	9.6	13.5	14.5	10.8	11.0	13.3	12.8	—
3	11.9	15.7	13.1	13.6	12.1	10.3	9.7	13.4	12.6	13.3	10.7	13.2	12.5	12.3
	Plants Utilizing Four-Fifths of Available Water Before Watering													
15	12.0	15.3	13.2	11.9	11.1	8.2	9.2	12.4	11.6	10.8	9.5	12.8	11.5	—
30	14.4	17.6	14.2	15.0	13.9	12.2	10.5	14.4	13.9	10.4	9.4	13.4	13.3	—
5	15.0	16.7	14.5	15.3	12 5	9.4	10.4	12.8	13.7	9.4	10.4	14.0	12.8	12.5
	Plants Utilizing All of Available Water Before Watering													
26	3.8	3.5	5.5	14.5	13.4	—	11.6	15.1	9.7	9.3	7.3	1.9	8.7	—
1	14.2	15.7	16.0	14.0	10.5	9.6	7.8	10.3	13.5	8.2	9.4	10.9	11.7	—
4	17.1	13.3	10.0	4.5	1.5	1.3	—	14.9	15.6	14.9	13.2	16.5	11.2	10.5

The average carbon dioxide intake values for the leaves in the four plots that were permitted to remove one-fifth, two-fifths, three-fifths, and four-fifths of the available moisture were not significantly different. With the trees that were permitted to remove more than four-fifths of the available moisture, there was an over-all reduction in carbon dioxide intake of about 15 per cent.

It appeared that the reduction in carbon dioxide intake occurred when the available soil moisture reached approximately 10 per cent, and several days before the leaves actually wilted. This is shown in Fig. 1 in which the soil moisture is plotted against the logarithm of the carbon dioxide intake of the foliage on trees that apparently had reduced the moisture to the wilting point as shown by the actual wilting of the leaves. The logarithm of the carbon dioxide intake

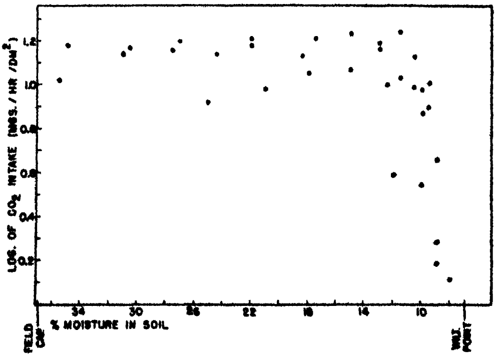

FIG. 1. Scatter diagram of the logarithm of carbon dioxide intake of apple leaves (Mgs/Hr/Dm^2) as related to soil moisture.

was used to accentuate the soil moisture per cent at which the reduction occurred.

The trees that were permitted to utilize the available soil moisture before the field capacity of the soil was again restored, showed a greatly reduced carbon dioxide intake for the several days in advance of wilting and with one tree, for the day following watering, probably as a result of a delay in recovery.

With tree 26, which was watered on April 26, the carbon dioxide intake on April 23 and 25 was only 3.8 and 3.5 Mgs/Hr/Dm^2, whereas 1 and 3 days after watering the carbon dioxide intake was 5.5 and 14.5 Mgs/Hr/Dm^2 respectively. Full recovery was not evidenced the first day following watering. On May 18, 22 days after water had been applied, the carbon dioxide intake had dropped to 1.9 Mgs/Hr/Dm^2, indicating that as the soil moisture again approached the wilting point, the carbon dioxide intake was again reduced.

Tree 1 showed a carbon dioxide intake of 9.6 and 7.8 Mgs/Hr/Dm^2, 4 days and 1 day before watering respectively as contrasted with an intake of 10.3 and 13.5 Mgs/Hr/Dm^2 1 and 4 days after watering. The soil with this tree, however, was not quite at the wilting point when the water was applied.

The carbon dioxide intake of the foliage of tree 4 was reduced to 4.5, 1.5 and 1.3 Mgs/Hr/Dm^2 7, 5, and 3 days respectively before water was added. This is contrasted with 14.9 and 15.6 Mgs/Hr/Dm^2 2 and 4 days after the soil moisture was again brought to field capacity. Full recovery was evidenced both by the carbon dioxide intake and by the appearance of the foliage, 2 days after watering.

The elimination of daily variation may be accomplished by the calculation of relative efficiencies of the leaves, using one treatment as a basis. The average relative efficiency of the leaves that utilized more than one-fifth of the available water, compared with the carbon dioxide intake of the leaves that utilized only one-fifth of the available water as 100, is presented in Table IV.

TABLE IV—RELATIVE EFFICIENCY OF LEAVES IN ABSORBING CARBON DIOXIDE WITH THE DAILY AVERAGE CARBON DIOXIDE INTAKE OF PLANTS REMOVING ONE-FIFTH OF AVAILABLE WATER BEFORE WATERING AS 100

Soil water content:–	Above 30.5 Per Cent	25 to 30.5 Per Cent	19 to 24.5 Per Cent	13 to 18.5 Per Cent	Below 12.5 Per Cent	Averages
Plants utilizing two-fifths of available water	103 (17)[*]	100 (15)	100 (2)	—	—	101
Plants utilizing three-fifths of available water	102 (2)	101 (18)	97 (12)	94 (4)	—	99
Plants utilizing four-fifths of available water	99 (2)	98 (10)	103 (12)	99 (9)	97 (3)	101
Plants utilizing all the available water	107[†] (2)	101 (4)	110 (4)	115 (7)	55 (14)	83
Average	102	101	101	103	62	

[*] Numbers in parenthesis refer to number of determinations.
[†] Not including two determinations made less than 24 hours after watering.

In Table IV the individual trees were grouped together on the basis of the respective plots into which they were placed, and on the basis of the moisture content of the soil at the time the carbon dioxide intake by the leaves was determined. This latter division was made on the same basis that determined the plots, that is, up to one-fifth of available water removed, between one-fifth and two-fifths removed, and so on.

The only plot that showed much variation from 100 is the plot that was permitted to remove all of the available soil moisture. The efficiency was somewhat higher than the other plots until more than four-fifths of the available moisture was removed. The average efficiency of the leaves when more than four-fifths of the moisture had been removed was 55, or the leaves were functioning at only approximately one-half their capacity.

The maximum reduction in carbon dioxide intake shown in Table III was about 87 per cent below the average of the unaffected trees, this reduction occurring with the foliage on tree No. 4 at the wilting point, as shown by the foliage. This is in general agreement with the work of Schneider and Childers (9) who reported a reduction in carbon dioxide intake of 87 per cent at the wilting point.

It is interesting to note that whereas the trees that removed four-fifths of the available water before watering did not show a reduced carbon dioxide intake, they utilized considerably less water and grew less than did the plants that utilized one-fifth, two-fifths, and three-fifths of the available water before water was applied. This may indicate that the ease with which an apple tree may remove water is reduced after three-fifths of the available water has been utilized. It may also indicate that the rate of growth is retarded before a reduction in carbon dioxide intake occurs. A loss of cell turgor may be responsible for the reduction in growth of these trees.

SUMMARY

Apple trees growing in the greenhouse did not show a reduction in apparent photosynthesis until more than four-fifths of the available soil water had been utilized. This reduction occurred when the soil moisture was reduced to about 10 per cent, as shown by the tensiometers, or about 3 per cent above the wilting point, and as much as a week before wilting of leaves occurred.

Trees utilizing four-fifths, and all the available moisture before watering, utilized considerably less water, and grew less during the course of the experiment than did plants that removed three-fifths or less of the available moisture before water was applied.

The reduction in growth with trees that utilized four-fifths of the available water was not a result of a decreased rate of photosynthesis since no reduction in rate of carbon dioxide assimilation occurred, but may have been a result of loss of cell turgor.

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Summer Sprays with Potassium a-Naphthaleneacetate Retard Opening of Buds on Fruit Trees

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DURING the past several years various indole, phenyl, naphthalene, naphthoxy, and phenoxy compounds were applied in the form of solutions, emulsions, powders, and vapors to trees, shrubs, herbaceous plants, and storage organs. The object of these tests was to determine the influence of these hormone-like compounds on the time the buds opened, fruit set, parthenocarpic development of fruit, modification of organs, inhibition of the growth of buds, leaves, and shoots, persistence of floral parts, and the abscission of flowers, leaves, and fruit.

On September 13, 1940, sprays containing potassium a–naphthaleneacetate (KNA) in concentrations of 100, 320, and 1000 mg/l were applied to branches of apple, cherry, peach, pear, and plum trees located in the Institute orchard. These same sprays were also applied to McIntosh apple trees on September 16, 1940, in connection with fruit-drop tests (1, p. 106). In the spring of 1941 it was observed that branches receiving the highest concentration of KNA were noticeably delayed in the opening of flower and vegetative buds. The degree of retardation varied according to the concentration of KNA and the variety of fruit. These results were more consistent and exhibited a more striking influence of the concentration of KNA than the results obtained over a period of several years with similar bud-inhibiting substances applied in the spring. Thus it appeared that the retardation of bud growth could be accomplished more effectively by treatment during the summer than in the spring when the buds were out of their rest period and ready to grow.

Similar treatments were applied to fruit trees during the year 1941. In these tests KNA was used in concentrations of 200, 400, 800, and 1000 mg/l with 0.1 per cent Aerosol OT (Vatsol OT) as a spreader. The sprays were applied on July 21, August 20, and September 17. Results of these tests not only confirmed those of the previous year, but in addition, showed that the degree of delay in bud opening also depended upon the time of applying the spray. The present paper deals with the results of the 1941 treatments and their possible significance in relation to the regulation of growth in general.

MATERIALS AND METHODS

The concentrations of KNA mentioned above were applied as a single application to two or more branches of the following varieties of fruit trees: apple (Stayman Winesap, McIntosh, Baldwin, Rhode Island Greening, Grimes Golden), cherry (Montmorency, Black Tartarian, Windsor), peach (Carmen, Elberta, Mountain Rose), pear (Bartlett, Seckel), and plum (Burbank, Abundance). The 1000 mg/l spray was applied only on September 17. The other concentrations of 200, 400, and 800 mg/l were applied with a knapsack sprayer on

July 21, August 20, and September 17. Apple and cherry received a more complete series of treatments and more replications than the other kinds of fruit trees.

RESULTS

On April 14, 1942, an examination of the treated branches in the orchard revealed that certain treatments had delayed the development or growth of flower and vegetative buds on all varieties of fruit trees. The degree of inhibition varied according to the concentration of KNA, the time the spray was applied, and the variety of fruit tree. Between the 20th and 24th of April it became apparent that the vegetative buds were generally delayed to a greater extent than flower buds. The difference was most pronounced for buds receiving the 400 and 800 mg/l sprays in July. This preferential effect on flower and vegetative buds became less marked with later applications or with the lower concentrations at any given time.

Although a complete series of treatments was not applied to all varieties of fruit trees, a description of the results for Montmorency cherry can be considered as representative of the results as a whole for the other kinds of fruit trees. The influence of the time of application of the spray upon the delay in bud development is illustrated for the intermediate concentration (400 mg/l) in Fig. 1, A. Sprays applied in July had the greatest retarding effect and those applied in September had the least effect. The influence of the concentration of KNA on delayed opening of buds is illustrated for the July application in Fig. 1, B. The increased delay resulting from an increase in concentration (Fig. 1, B) was relatively the same as that due to the difference in time of application (Fig. 1, A). The 200 mg/l spray was about as effective when applied in July as a 400 mg/l spray in August, or an 800 mg/l spray in September. Of the treatments applied in September the 800 mg/l spray was the only one which was noticeably effective. In contrast, the lowest concentration used in July (200 mg/l) was not low enough to be considered as the minimum effect dose for Montmorency cherry.

Flower buds located on spurs were generally delayed to a greater extent than those on 1-year-old shoots. The opening of flower buds was delayed from a few days to 14 days depending upon the concentration and time of applying the spray. Vegetative buds were delayed similarly up to 19 days. Terminal vegetative buds were retarded to a lesser extent than side buds. The treatments which caused the greatest delay in opening of flower buds brought about a condition similar to that illustrated in Fig. 1, B whereby at the time of flowering there were few or no leaves. The relative amount of leaf surface on control and treated branches at the time of full bloom varied considerably with different varieties of cherry and other kinds of fruits.

The greater the dosage, the fewer the number of flower buds which opened. Some of the treated buds were dead, but many remained alive at least until May 14 when last examined. In the spring, treated flower buds which were smaller than control buds were generally the latest to open. When these smaller buds opened, the flowers were similar in appearance to the controls except in the case of buds receiving the

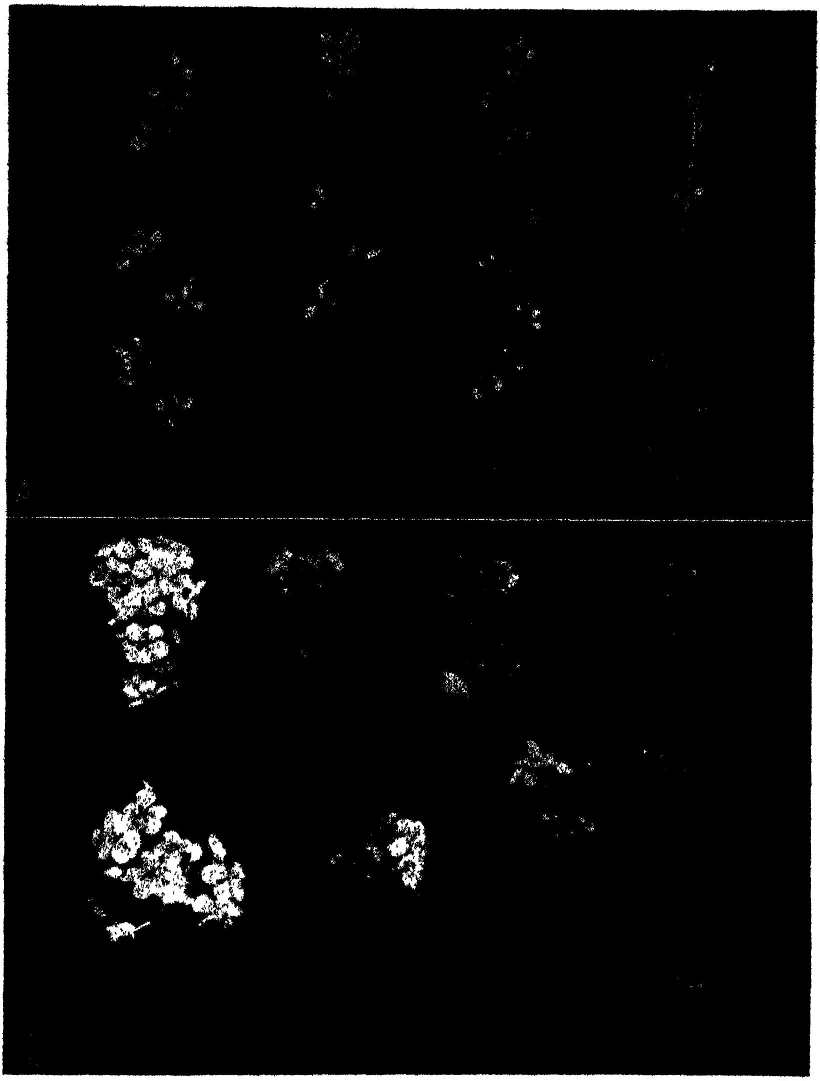

FIG. 1. Montmorency cherry showing the influence of concentration of potassium a–naphthaleneacetate and the time of applying the spray. A, 400 mg/l applied (left to right) control, September 17, August 20, and July 21, 1941. Photographed April 22, 1942. B, (left to right) control, 200, 400, and 800 mg/l applied July 21, 1941. Photographed April 30, 1942.

July application of 800 mg/l. In the latter case at least some of the flowers appeared to be of slightly smaller diameter or had shorter peduncles than the controls. The smaller size of some of the treated buds was observed in November as well as in early spring.

Fruit set on treated branches was delayed slightly and appeared to be spread over a longer period as compared with the controls. The

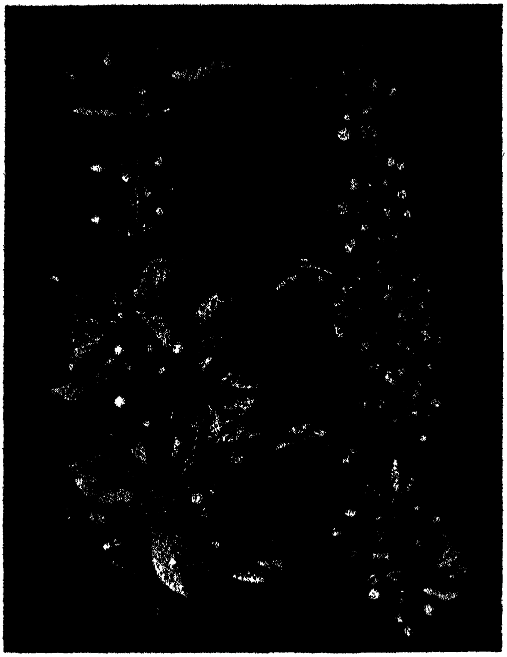

FIG. 2. Montmorency cherry photographed May 14, 1942. Left, control. Right, sprayed July 21, 1941 with 200 mg/l potassium a-naphthaleneacetate.

development of the fruit on treated branches appeared to proceed at a normal rate, but due to the initial delay in fruit set there was a greater range in size of green fruits on treated branches than on controls (Fig. 2). Ripe fruit had the same general appearance on treated and control branches.

The results thus far described apply not only to Montmorency cherry but also to the varieties Black Tartarian and Windsor. In contrast, the apple was slightly more resistant and the peach and plum more sensitive than the cherry. Thus the optimum treatment varied with the kind of fruit.

DISCUSSION

Since the potassium salt of a-naphthaleneacetic acid was effective in delaying the opening of flower buds from 1 to 2 weeks, it seems likely that the acid, amide, and ester forms would be equally or perhaps even more effective. Likewise, other substances known to have growth-inhibiting properties such as certain indole, naphthoxy, and substituted phenoxy compounds, and so on, would probably give similar results. If the solubility limits in water of the acid, amide, or esters of naphthaleneacetic acid are exceeded, as in the present tests, either the salts must be used or the active ingredient must be incorporated in an emulsion or in a solvent other than water. However, since the lower concentration of 200 mg/l was effective when applied in July, there would appear to be no necessity for using the higher concentrations which would be required for later applications in the latter part of August or in September. On the basis of the 1941 tests it is believed that concentrations of 100 to 200 mg/l of naphthaleneacetic acid applied to Montmorency cherry during the first part of August would cause a noticeable delay in the opening of flower buds without causing a serious reduction in leaf area or yield of fruit.

The possible practical uses of bud-inhibiting substances are not confined to delaying the opening of buds on fruit trees. In other tests the opening of flower buds on potted lilac plants was delayed 10 to 14 days by naphthaleneacetic acid applied in the form of a spray.

Treatments with the methyl and ethyl esters of a–naphthaleneacetic acid, which induced parthenocarpic development of fruit on *Ilex opaca,* also delayed the opening of buds for one year, even though these plants were subjected later to the usual low temperature period. Regulating the growth and development of plants in general has been contemplated by nurserymen for many years. Flowering of ornamental plants might be delayed with treatments during the growing season as in the case of fruit trees. In this way the time of blossoming could be staggered on the same plant or on different plants so as to extend the total period of flowering. Besides this effect it seems likely that proper treatment of plants just before or after the flower buds open might increase the lasting qualities of the flowers as reported for *Ilex opaca* (2) and the tomato (3).

Considering the increased demand for transplanting trees and shrubs at any and all times of the year, there might be a special application of growth regulating substances as described in the present tests or for the purpose of delaying or stopping the growth of leaves or shoots at any stage of development. For example, in connection with camouflage work in the present war program, it is necessary to transplant woody plants in late spring and early summer at a time when the high water and nutrient requirements of rapidly developing leaves and shoots make transplanting difficult.

SUMMARY

Potassium a–naphthaleneacetate (KNA) was applied as a spray in concentrations of 200, 400, and 800 mg/l on July 21, August 20, and September 17 to apple, cherry, peach, pear, and plum trees. The delay in opening of buds the following spring ranged from a few days to 14 days for flower buds and up to 19 days for vegetative buds, depending upon the concentration of KNA, the time of application, and the variety of fruit. For cherry, a concentration of 200 mg/l applied in July was about as effective as 400 mg/l in August, and 800 mg/l in September. The optimum time of treatment for cherry appears to fall in the month of August. Peach and plum were more sensitive than the other kinds of fruits. The possibility is discussed of using inhibiting substances to retard or otherwise regulate the growth and development of buds, flowers, leaves, and shoots of plants in general.

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Set of Citrus Fruits in Relation to Applications of Certain Growth Substances

By C. S. Pomeroy and W. W. Aldrich, *U. S. Department of Agriculture, Riverside, Calif.*

SINCE some citrus varieties in the Southwest frequently fail to set sufficient fruits to provide a satisfactory crop, a study of certain factors which might influence fruit set was begun at Riverside, California in 1938. Flowers of the Washington Navel orange in California normally produce no pollen and only rarely is a seed found in fruits of this variety even when planted near trees of other commercial citrus varieties. Both the Valencia orange and the Marsh grapefruit produce only small amounts of pollen, much of which is not viable, and their fruits usually have very few seeds. The setting of parthenocarpic fruits as a result of applications of certain growth substances to the flowers of a number of seed-producing plants, as reported by Gustafson (2) and by Gardner and Marth (1), suggested that the stimulus of some synthetic growth substance might increase the set of citrus fruits in the Southwest.

In April and May, 1938, alpha-naphthaleneacetic acid was applied to Washington Navel trees in three ways: (a) Aqueous solutions of 0.04, 0.01 and 0.004 per cent were sprayed on the stigmas of open flowers and on cut or broken styles; (b) a 0.01 per cent aqueous solution was applied continuously for about 5 weeks through holes bored into the branches; and (c) a 0.02 per cent concentration in lanolin was applied on the broken styles of pistils and to the stylar scars of very small fruit. For each branch receiving one of these treatments, a control was provided by applying water or plain lanolin on a nearby branch. About 10,000 flowers on 24 trees were included in these tests.

The average percentages of treated blossoms that set fruit were, in general, slightly less than for the controls. The much lower fruit set with the 0.04 per cent spray and from the infiltration of branches suggested that relatively high concentrations of naphthaleneacetic acid had an inhibiting effect upon set. In no case, however, was any physical injury apparent on any flowers. Naphthaleneacetic acid applied as a spray to a few flowers of Booth and White cherimoyas and of Wilson and Pike white sapotes did not increase the final set of fruit, but it did seem to delay the drop of some cherimoya fruits.

In 1939 the treatments on Washington Navel orange included the application of naphthaleneacetic acid, indoleacetic acid, indolebutyric acid, furacrylic acid, and calcium furoate at concentrations of approximately 0.1 per cent in water or 0.4 per cent in lanolin. In addition, young leaves just below flower clusters were dipped in an aqueous naphthaleneacetic acid solution while the submerged terminal third of each leaf was severed with scissors, in the hope that some of the solution might be drawn into the leaves and affect fruit set of nearby flowers. For comparison with the growth-substance treatments, pollens of St. Michael orange, Meyer lemon, Coleman citrange, a shaddock, and the Fard No. 4 date were applied by hand to about 700 flowers on 25 trees. The pollen of this male date had been found by F. E. Gardner to have an active supply of auxin. Neither the treatments with growth substances nor the applications of citrus pollen appreciably affected either the initial or the final set of fruit, but the date pollination showed a 35 per cent higher fruit set than the control.

In 1940, additional tests were made with 0.01 per cent naphthaleneacetic acid solutions and with pollen of the Fard No. 4 date and of seedy grapefruit varieties. Groups of carefully matched flower buds were selected for the treatments. When flower clusters rather than single flowers were chosen, all flowers but one in each cluster were removed before treatment. Where sprays were applied, the tips of petals and styles were cut away to expose the shortened style and the ovary. The treatments were applied to Marsh grapefruit at Indio as well as to Washington Navel orange at Riverside. A summary of the 1940 results is given in Table I. The final fruit count was made in May before normal fruit drop was complete, so the percentages of set are abnormally high. Spraying flowers with naphthaleneacetic acid resulted in about the same set of fruit as spraying with water (control). Dipping leaves in naphthaleneacetic solution was followed by a lower percentage set of fruit than in the control, although with grapefruit the odds for significance were only about 13 to 1. Hand application of Fard No. 4 date pollen had no effect upon the set of orange fruits, but seemed to reduce the set of grapefruit. However, the application of pollen of seedy grapefruit varieties resulted in a higher set of both orange and grapefruit than did open pollination.

TABLE I—PERCENTAGE OF FLOWERS SETTING FRUIT IN 1940, FOLLOWING TREATMENTS WITH 0.01 PER CENT NAPHTHALENEACETIC ACID AND APPLICATIONS OF DATE AND OF CITRUS POLLEN, IN COMPARISON WITH CONTROLS

Treatment	Percentage of Flowers Setting Fruit for Each Treatment, in Comparison with the Respective Control	
	Treatment Per Cent	Control Per Cent
Washington Navel Orange—Flowers Treated April 3 to 6—Fruits Counted May 27		
Naphthaleneacetic acid—spray	0.6	2.2
Naphthaleneacetic acid—leaf dipping	2.8*	4.5
Pollination—Fard No. 4 date	4.3	5.2
Pollination—Pernambuco grapefruit	34.5*	5.2
Marsh Grapefruit—Flowers Treated March 16 to 23—Fruits Counted May 16		
Naphthaleneacetic acid—spray	0.4	0.0
Naphthaleneacetic acid—leaf dipping	8.2	10.5
Pollination—Fard No. 4 date	2.9†	11.8
Pollination—Foster grapefruit	22.1†	11.8

*Difference in comparison with control was significant at 1 per cent level.
†Difference in comparison with control was significant at 5 per cent level.

The potential capacity of the various growth substances for stimulating fruit set was determined by spraying flowers of the purple trailing lantana (*Lantana sellowiana*), which normally does not set fruit at Riverside. Neither the furacrylic acid nor the calcium furoate, in the 0.1 per cent concentration used, stimulated set of fruit; but treatments with naphthaleneacetic acid, indoleacetic acid, and indolebutyric acid did result repeatedly in the development of fruit on 20 to 60 per cent of the lantana flowers, provided they were sprayed after the corollas were removed. Naphthaleneacetic acid solutions held one year were found to be as effective on lantana as fresh solutions. When, however, the corollas were not removed, spraying the lantana flowers did not cause fruit to set. Since the corolla of the lantana apparently prevented penetration of the stimulus of the growth substance, it seems possible that ovary tissue of the citrus flower may also have failed to transmit this stimulus.

SUMMARY

The application of naphthaleneacetic acid and other growth substances did not increase the percentage of flowers setting fruit for Washington Navel orange and for Marsh grapefruit. The pollen of Pernambuco and of Foster varieties of grapefruit did increase the set of fruit, indicating that one factor limiting the set of fruit of the citrus studied might be a lack of the stimulatory effects of pollination.

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Growth Regulators and Fruit Set With Starking Apples[1]

By LAURENZ GREENE, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

GARDNER and Marth (1), McCown and Burkholder (2), and Varrelman (3) have reported failures in attempts to increase the set of fruit in Starking and other varieties of apples by the application of growth substances to the blossoms.

Despite these failures, the success being obtained in other plants makes desirable continued efforts to improve the fruit set of varieties like Starking.

While Starking is notorious for its poor set in some years even when ample pollination is provided, it set very well in 1942 under the conditions reported here. Check branches set fruits on 22 to 96 per cent of their blossoming spurs, with the majority setting 30 to 50 per cent indicating open pollination was efficient. These checks were quite variable, from tree to tree and from branch to branch on the same tree.

Where floral parts were removed and lanolin paste, containing naphthaleneacetic acid, indolebutyric acid, indoleacetic acid, or indolepropionic acid, was smeared on the cut style or on the cut style and over the receptacle, all blossom parts died or failed to enlarge. Some persisted for several weeks. Where floral parts were not removed and the lanolin paste was smeared over the pistil and around the floral parts including the receptacle, no fruit set and all floral tissues died.

Lanolin paste containing any of the four substances reduced or prevented the set of fruit when it was smeared onto the pistils. In the case of naphthaleneacetic acid in lanolin 12 per cent of the blossoming spurs set fruit. No fruit set with the other three. No seedless fruits were produced indicating that the flowers had been pollinated previously.

Applications as sprays were not always so destructive. With 0.1 per cent polyvinyl alcohol as a carrier for naphthaleneacetic acid at concentrations in water solutions of 0.01 per cent, 0.005 per cent, and 0.001 per cent the set was reduced in all cases, with the greater reductions at the higher concentrations. Indolebutyric acid at 0.001 per cent and 0.005 per cent plus polyvinyl alcohol in water solution reduced the set very little if at all.

Wax emulsions have been used by Withrow, Blodgett, and Howlett (4) to maintain a supply of growth substances over a longer period of time. The first of these used on apples consisted of 0.3 per cent naphthaleneacetic acid, 5 per cent Opal Wax, 2 per cent polyvinyl alcohol–R.H.488, and 0.5 per cent sorbitol. This spray applied on April 27th prevented fruit set and there was serious injury to foliage and floral parts. Some spurs were killed. Flowers, less the petals, persisted for several weeks. One fruit about ¼ inch in diameter persisted till September. Indolebutyric acid emulsion was less injurious and some fruit set. (Withrow supplied the emulsions used in these tests).

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[1] Journal Paper No. 69 of the Purdue University Agricultural Experiment Station.

As these emulsions prevented abscission of the pedicels and receptacles, young fruits were sprayed with an emulsion containing a lower concentration on May 23 after the first and most of the second wave of fruit drops had occurred. It was hoped to prevent further drop. The second emulsion contained 0.01 per cent naphthaleneacetic acid, 2.5 per cent Opal Wax, 1 per cent polyvinyl alcohol–R.H.647, and 0.5 per cent sorbitol.

These sprays did not reduce the set as practically all fruit persisted on sprayed and check spurs but they did retard the growth of the sprayed fruits. By September first the sprayed fruits were approximately one-half the size (by weight), of unsprayed fruits on the same branch.

Fruits sprayed with the second emulsion diluted to one-third the above strength were about 80 per cent as large as unsprayed fruits on the same branch and those sprayed with a solution one tenth as concentrated were about 90 per cent as large as unsprayed fruits.

While it is difficult to control the concentrations of injected liquids at growing points due to transpiration, several attempts were made to test this method by introducing the liquid into the branch through borings or cut shoots. Naphthaleneacetic acid, indolebutyric acid, sugar, urea, and ammonium sulphate were tried separately. None of these increased the set. Naphthaleneacetic acid at a concentration of 0.01 per cent distinctly injured the foliage and the fruit was smaller as a result. At 0.001 per cent there was no apparent injury and at harvest the fruits were one-fourth larger than those on check branches. With indolebutyric acid at 0.001 per cent concentration used as an injection there was slight damage to the foliage and the resulting fruits were about one-sixth larger than their checks. With the variability from tree to tree and from branch to branch, too few replications were provided to make these results more than suggestive.

SUMMARY

No increased set of fruit was secured from the growth substances used whether in lanolin paste, as sprays with carriers or as injections into the branch.

Naphthaleneacetic acid in wax emulsion sprayed onto small fruits nearly a month after full bloom retarded the growth of those fruits and prevented their normal development.

All of these compounds seem to be more toxic to apple tree tissue than to other plants. Concentrations at 0.005 per cent or higher would appear to be unsafe.

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Di-Nitro Compounds Employed as Sprays to Reduce Fruit Set in the Apple

By Freeman S. Howlett, *Ohio Agricultural Experiment Station, Wooster, Ohio*

THERE has been a great increase of interest recently in the application of sprays to apple trees either to thin the crop or to prevent fruit production altogether.

Spray materials originally used for this purpose were the tar oil distillates, but recently attention has shifted to the so-called di-nitro compounds. A possible reason for this change is that the composition of tar oil distillates varies considerably, whereas the di-nitro sprays involve one effective chemical, the concentration of which may be kept reasonably constant from year to year. This characteristic of the di-nitro sprays makes it possible to conduct over a period of years tests employing various concentrations, each of which can be repeated with the exact amount of the one effective chemical known, a situation not at all possible with the tar oil distillates.

All such tests with chemicals have been largely exploratory, with the objectives of ascertaining whether the material employed would reduce fruit set without excessive injury to foliage and spurs and of ascertaining what concentration would produce the most favorable effects in flower thinning and fruit removal.

Work at the Ohio Agricultural Experiment Station at Wooster has been conducted primarily with trees bearing alternately heavy and light crops or no crops in the "off" year. The purpose of using such trees has been to observe the effect of the treatment upon flower bud differentiation for the succeeding year's crop. Tests with annual-bearing trees are satisfactory if the effect of the material in thinning the current crop is to be studied, but obviously the effect upon changing the year of alternation cannot be obtained by using such trees.

Because of lack of trees of standard commercial varieties, the work reported here has been concerned in part with some varieties which are of little or no commercial importance. However, the tests do include Cortland, Baldwin, Grimes Golden, Melba, Northern Spy, Oldenburg, and Wealthy.

Tests were made on 24 apple varieties during the period 1940 to 1942. The trees were growing in the Station orchards either in mulch or sod with additional nitrogen. They ranged in age in 1940 from 14 to 48 years.

Before spraying, two carefully selected limbs on each tree were covered with large paper bags, 6 feet by 3 feet. The trees were then thoroughly sprayed with a gun. A 300-gallon sprayer employing 500 pounds of pressure was used. The bags were removed from the limbs as soon as the foliage had dried. Counts of the number of flower clusters were made on these unsprayed branches, as well as on two representative sprayed branches (usually forming a V-shaped pair with the unsprayed branch). The number of fruits set per cluster and the number of flowering clusters bearing fruits were counted both after the first and the second (June) drop. The sprays were applied, unless otherwise indicated, when the trees reached full bloom, that is when 80 to 100 per cent of the flowers were at anthesis. Only limited attention was given to sprays applied either during the early or late cluster bud stage.

The di-nitro compounds applied were contained in the following proprietary materials:

1. Elgetol-containing sodium di-nitro-cresylate, 29.5 ounces of the effective chemical to 1 gallon
2. Dow Compound No. D–41 (DN Dry Mix No. 1) of the following composition:

Dinitro-ortho-cyclo-hexyl-phenol	40 per cent
Bentonite	40 per cent
Soybean flour	20 per cent

3. Dow Compound No. D–145 (DN Dry Mix No. 2)

Dinitro-ortho-cresol	40 per cent
Bentonite	60 per cent

The Dow materials were employed in an oil emulsion containing 2 gallons of Shell spray oil.

PRESENTATION OF THE DATA

Results in 1940:—The spray was applied primarily to thin the fruits, since the trees used were bearing more or less annually. The spray was applied (with one exception) during bloom. Table I shows that the spray at 0.3 per cent concentration did not appreciably reduce the yield. Injury to the opening leaves of Moyer was extensive, but there was no effect upon the crop.

TABLE I—EFFECT OF ELGETOL UPON FLOWER ABSCISSION AND FRUIT SET (0.3 PER CENT CONCENTRATION, 1940)

Variety and Tree Number	Percentage of Flowers Setting Fruit				Yield of Tree (Bushels)			
	After First Drop		After Second Drop					
	Unsprayed	Sprayed	Unsprayed	Sprayed	1939	1940	1941	1942
Hume H-146	11.5 5.5	10.6 13.5	6.1 3.4	4.4 3.4	3.1	5.2†	2.5	3.0
Joyce H-147..	27.6 36.8	16.2 27.7	12.4 7.0	5.3 6.4	5.0	5.2	9.5†	2.0
Moyer A-129*.	—	—	1.3 1.6	3.9 1.2	5.0	12.5†	3.6	10.0

*Applied in late cluster bud.
†Equivalent to full commercial crop.

Results in 1941:—The data presented in Table II indicate that a material may reduce the percentage of flowers setting fruit after the first drop but that the difference between sprayed and unsprayed branches may be nearly obliterated by the greater second drop from the unsprayed branches. Examples of this condition are results from the varieties Anoka, Glenton, and Oldenburg receiving 0.6 per cent Elgetol. Anoka and Glenton had a full commercial crop at maturity,

TABLE II—EFFECT OF ELGETOL UPON FLOWER ABSCISSION AND FRUIT SET (1941)

Variety and Tree Number	Per Cent of Flowers Setting Fruit				Per Cent of Flowering Clusters With Fruit		Yield of Tree (Bu)			
	After First Drop		After Second Drop		After Second Drop		1939	1940	1941	1942
	Un-sprayed	Sprayed	Un-sprayed	Sprayed	Un-sprayed	Sprayed				
Elgetol, 0.6 Per Cent, Applied Once										
Anoka F-625	69.6 55.8	38.7 44.5	48.5 19.7	25.0 16.1	88.9 48.0	55.0 47.0	5.0	3.0	7.0*	2.0
Baldwin A-128	35.8 17.3	10.9 29.5	5.3 6.3	5.2 3.3	25.0 25.0	19.6 14.0	33.6*	2.2	21.5	1.4
Cortland H-151	41.6 24.6	1.9 1.4	0.6 1.4	0.0 0.0	3.1 5.4	0.0 0.0	5.5*	0.6	0.0	4.0
Cortland A-173	—	0.0	—	0.0	—	0.0	6.2	0.3	0.0	4.0
Elmer F-627	70.7 73.7	40.8 48.6	38.6 34.6	32.2 12.4	72.8 68 5	75.5 28.6	22.0*	0.0	9.0	0.8
Glenton F-634	94.8 66.5	42.3 38.2	8.7 8.1	10.6 6.2	34.8 22.5	34.0 21.8	19.9*	4.0	—	0.0
Oldenburg A-228	36.1 47.3	11.5 11 6	6.7 8.8	3.8 5.9	32.9 38.0	17.8 22.9	6.0	2.5	5.0	1.8
Ralls A-239	16.0 32.6	15.6 26.2	10.3 8.3	4.2 6.9	39.7 24.6	17.3 24.5	25.0*	1.0	17.0	10.0
Ralls A-240	16.5 21.5	22.3 21.3	15.7 14.9	8 6 14.9	59.8 45.8	40.7 62.0	22.0*	0.5	14.5	7.5
York Imperial A-309	14.5 17.4	3.7 10.4	2.9 2.6	0.0 0.0	13.6 13.2	0.0 0.0	17.3	0.3	0.4	7.0
Elgetol, 0.8 Per Cent, Applied Once										
Joyce H-145	10.3 24.1	20.8 26.9	7.0 15.7	9.6 9.0	31.9 59.8	22.8 33.8	5.2*	2 5	5.0*	4.3
Melba H-156	18.3 41.1	10.3 10.0	6.6 23.2	1.3 3.8	31.7 76.0	6.3 18.8	1.2	0.1	1.0	8.0*
Elgetol, 0.6 Per Cent, Applied Twice										
Cortland H-116	73.8 62.7 —	27.6 (1) 0.9 (2) 0.0 (2)	4.3 0.6 —	0.0 (1) 0.0 (2) 0.0 (2)	20.0 3.1 —	0.0 (1) 0.0 (2) —	5.0*	2.5	0.2	3.5
Joyce H-154	51.6 44.0 —	50.5 (1) 10.2 (2) 18 4 (2)	1.8 5.3 —	8.9 (1) 1.1 (2) 2.7 (2)	8.8 20.8 —	31.1 (1) 5.5 (2) 11.3 (2)	3.4	2.4	3.0	4.5
Melba H-150	40.5 32.2 24.6	9.3 (1) 2.2 (2) 1.0 (2)	9.0 3.5 1.4	0.0 (1) 0.0 (2) 0.0 (2)	36.6 17.4 7.0	0.0 (1) 0.0 (2) 0.0 (2)	3.0*	0.1	0.2	3.0*
Porter F-638	64.1 90.0 —	17.5 (1) 3.7 (2) 0.0 (2)	17.0 22.7 —	6.4 (1) 2.8 (2) 0.0 (2)	47.9 63.6 —	26.8 (1) 12.8 (2) 0.0 (2)	23.0*	1.0	3.0	4.3

*Equivalent to full commercial crop.

but Oldenburg had slightly less than a full crop. Roughly, the fruiting of 25 to 30 per cent of the flowering points, or one fruit cluster in three to four flowering clusters, is the approximate equivalent of a full commercial crop requiring no hand thinning. This index was used in evaluating the results.

The 0.6 per cent Elgetol slightly reduced the yield of Baldwin and Oldenburg below a full crop and removed all fruits from the sprayed portions of Cortland and York Imperial. It was surprising to note such a heavy second (June drop) from the unsprayed portions, since their leaves were not injured by spraying. Ralls was not affected to any significant extent by the spraying.

With 0.8 per cent Elgetol, Joyce was unaffected, but Melba was greatly thinned. The foliage injury to each was extensive, with no observable difference between the varieties.

Two sprays at 0.6 per cent produced different effects on the four varieties employed. The crop on Melba and Cortland was removed by the first spray, while that of Joyce was unaffected. On the other hand, Joyce was considerably thinned by the second, and Porter was thinned by both sprays.

It should be emphasized that the foliage open at the time of spraying was greatly injured. In a number of instances, some spurs, invariably the weaker ones, were also killed. The secondary shoots from the cluster base were also injured or killed in a few cases, particularly with the two Elgetol sprays. However, all the trees made a remarkable recovery.

Despite the foliage injury, attention is directed to the amount of flower bud differentiation which took place as indicated by the yield of the trees in 1942. Cortland and Melba produced at least a moderate, and in some instances a full, crop despite the injury from either one or two sprays. On the other hand, York Imperial and Porter did not produce a crop commensurate with the reduction in yield brought about by the spraying, probably because of the severe foliage injury.

Table III presents data for di-nitro-ortho-hexylphenol applied at the rate of 3.2 ounces to 100 gallons of oil emulsion. The spray applied during the pink stage to the four varieties reduced the yield of Atlas and removed the fruits on Newtosh but had no effect upon Patricia and Walker Beauty.

The tree of Baldwin was not thoroughly sprayed at the top, in consequence of which a fair yield was obtained in that portion. However, the differences between the sprayed and unsprayed portions in the center periphery of the tree indicated great reduction from the spray. The fruits were practically removed from Joyce, Melba, and Monmouth Beauty. Nearly all the foliage exposed at the time of spraying was killed, but recovery was remarkable, and there were sufficient flower buds differentiating for practically a full crop in 1942. On the other hand, the material applied in water to four varieties caused only a crinkling of the leaves, and no effect upon fruit set.

Results in 1942:—The trees, except Newtosh, receiving Elgetol were in full bloom. However, only one of two flowers of a cluster were open on Niobe and Northern Spy, which received di-nitro-ortho-cresol. The other trees receiving this spray had just reached full bloom.

Elgetol at 0.4 per cent concentration (11.8 ounces of sodium dinitro-cresylate) removed the crop from Grimes Golden and thinned greatly that on Joyce, Melba, and Newtosh. The Wealthy trees required some hand-thinning.

TABLE III—Effect of Di-Nitro Sprays Upon Flower Abscission and Fruit Set (1941)

Variety and Tree Number	Per Cent of Flowers Setting Fruit				Per Cent of Flowering Clusters With Fruit		Yield of Tree (Bu)			
	After First Drop		After Second Drop		After Second Drop					
	Un-sprayed	Sprayed	Un-sprayed	Sprayed	Un-sprayed	Sprayed	1939	1940	1941	1942
D N Dry Mix (D-41), ½ Pound in 100 Gallons of Oil Emulsion (2 Per Cent)										
Atlas H-121*	45.6 55.5	19.7 23.7	16.0 8.4	5.0 3.1	52.0 32.3	23.3 13.6	1.5	1.6	—	1.5
Baldwin A-117	15.6 34.3	1.2 8.4	5.3 5.1	0.4 1.3	25.4 23.1	1.9 1.3	13.0	1.5	14.5	0.5
Joyce H-146	74.8 33.3	0.0 0.9	29.6 18.6	0.0 0.4	74.1 53.6	0.0 0.2	5.0	1.2	1.0	8.0‡
Melba H-149	37.2 40.6	1.4 4.1	14.9 10.6	0.0 1.3	47.7 45.5	0.0 6.4	3.5	0.0	1.0	3.1
Monmouth Beauty H-157	55.0 47.3	7.0 3.8	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	2.0	2.4	0.0	3.6
Newtosh H-126*	55.9 62.1	7.9 2.4	6.2 11.0	0.0 0.0	27.6 41.4	0.0 0.0	3.2	8.0‡	3.0	4.4
Patricia H-143*	47.6 31.8	27.8 36.7	25.2 22 4	17.2 30.2	72.7 58.8	59.5 76.4	2.5	0.0	8.2‡	0.0
Walker Beauty F-639*	22.6 13.6	24.0 7.9	3.8 7.0	6.3 2.6	18.1 34.0	28.5 13.2	20.0‡	19.2‡	24.0‡	9.7
D N Dry Mix (D-41), ½ Pound to 100 Gallons of Water										
Baldwin A-126	40.0 39.0	47.7 36.2	16.1 4.8	15.0 10.4	71.7 22.1	71.2 49.3	19.2	0.5	33.0‡	1.0
Cortland H-117	40.7 49.4	43.6 22.6	0.2 1.9	1.4 1.5	1.2 8.1	6.9 7.5	4.2	1.5	2.9	4.0‡
Joyce H-147	36.8 58.1	30.0 39.5	17.9 9.1	13.2 16.8	65.8 34.0	52.3 58.7	5.0	5.2	9.5‡	2.0
York Imperial A-111	18.7 16.6	17.9 18.2	11.7 8.5	8.4 6.2	54.5 41.9	40.3 31.1	28.0‡	10.0	25.0‡	13.5

*Spray applied when flowers were in pink stage.
‡Equivalent to full commercial crop.

Di-nitro-ortho-cresol (Compound No. 2) at the rate of 1.6 ounces to 100 gallons of oil emulsion removed the crop from Fall Jennetting. The spray greatly reduced the percentage of flowers setting fruit after the first drop on the other four varieties, but the greater second drop of the unsprayed branches greatly reduced the differences. The crop on the sprayed trees represented, in general, slightly less than the equivalent of a full commercial crop. Although the injury to the foliage was considerable, it was much less than occurred in 1941 with the stronger concentration of di-nitro-ortho-cyclo-hexyl-phenol. Many of the pedicels of unopened flowers were injured, a condition which resulted in considerable reduction in fruit set in Niobe and Northern Spy.

TABLE IV—Effect of Di-Nitro Sprays Upon Flower Abscission and Fruit Set (1942)

Variety and Tree Number	Per Cent of Flowers Setting Fruit				Per Cent of Flowering Clusters with Fruit		Yield of Tree (Bu)		
	After First Drop		After Second Drop		After Second Drop		1940	1941	1942
	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed			
Elgetol, 0.4 Per Cent									
Grimes Golden H-50	21.6 22.3	17.5 19.1	1.6 10.9	0.0 0.0	8.0 43.1	0.0 0.0	6.0	8.0†	1.0
Joyce H-145	24.2 28.7	14 0 3.7	17.8 16.9	6.4 1.5	55.3 62.5	32.4 6.1	2.5	5.0	4.3
Joyce H-153	33.1 46.4	21.9 23.2	3.7 8 4	1.2 2.0	15.8 33.8	6.4 10.0	0.2	0.0	0.4
Melba H-155	30.0 47.8	19.1 17.5	7.1 10.9	2.5 1.9	34.1 44.9	12.7 9.3	9.3†	0.0	6.7
Newtosh H-125	69.5 61.4	36.8 46.8	18.6 15.7	5.7 8.4	54.6 50.9	22.9 32 1	5.0	4.4	3.8
Newtosh H-126	64.1 30.2	29.7 28.6	10.3 5.5	2.8 1.2	43.1 27.6	13.5 6.2	8.0†	3.0*	4.4
Wealthy H-94	41.9 41.4	28.8 32.6	10.1 14.5	4.5 7.6	42.5 45.4	22.9 34.2	11.4†	1.0	7.3†
Wealthy H-95	50.7 40.1	38.4 25.2	9.2 13.0	8.4 6.0	35.0 42.5	33.9 25.2	13.6†	1.2	8.0†
D N Dry Mix No. 2¼ Pounds in 100 Gallons Oil Emulsion (2 Per Cent)									
Fall Jenetting A-331	5.2 2.6	4.4 0.1	3.5 1.3	0.0 0.0	17 1 9 4	0.0 0.0	19.0†	0.0	0.7
Loy A-151	16.3 17.7	7.7 8.4	9.6 7.4	5.3 4.4	39.6 29.8	24.4 19.5	40.0†	1.0	32.0
Niobe F-626	57.3 66.3	15.7 6.2	14.5 8.7	5.1 1.7	30.8 20.6	21.1 7.5	29.5†	5.4	22.8
Northern Spy A-146	13.8 6.2	4.3 4.3	5.6 1.5	1.5 2.6	27.7 7.6	7.6 13.0	31.0†	2.5	8.8
Yellow Transparent A-83	40.7 36.9	22.7 17.8	11.1 4.1	7.0 4.1	42.9 20.3	31.9 16.5	16.0†	2.0	12.3

*Sprayed also in 1941.
†Equivalent to full commercial crop.

DISCUSSION OF THE DATA

The data presented herein indicate that the problem of obtaining sprays to thin the crop or remove it altogether is a complex one. In the first place, varieties differed greatly in their fruit set following application of a material at a given concentration. Secondly, they appeared to differ in the number of flower buds differentiating for the succeeding year's crop following the spray application. For example, a concentration of sodium di-nitro-cresylate which practically removed the flowers from Cortland and Melba was relatively ineffective on Oldenburg and Wealthy. Furthermore, although no gross visible difference existed between the spray injury on York Imperial and Cortland, the former produced considerably fewer flower buds for the succeeding crop. These data thus lend support to the conclusion that the concentration required to thin the crop or to remove all flowers and fruits must be worked out for each variety.

Furthermore, environmental factors, such as air temperature and relative humidity during or after the application of the spray probably influence the amount of injury to the flowers, foliage, and spurs. It is conceivable that greater injury to flowers may occur at the higher air temperatures. These and other factors, such as those which influence the vigor of the trees, may account for seasonal differences in flower removal. That seasonal differences will occur is indicated in part by the effect of the 0.4 per cent Elgetol spray in 1942 and the 0.6 (first spray) and 0.8 per cent sprays applied in 1941 to the same variety. In fact, on the varieties as a whole, 0.4 per cent concentration in 1942 seemed more effective than the two higher concentrations applied in 1941. The seasonal factor (apart from the varietal factor) may be responsible in part for the differences between the work of MacDaniels and Hoffman (3) and Hoffman (2) and that presented herein. Hoffman reported more thinning of the fruit of Wealthy with 0.4 per cent Elgetol than obtained at Wooster on the same variety. Furthermore, 0.3 per cent Elgetol seemed more effective under their conditions than higher concentrations applied in these tests, but the varieties are different. The work in Ohio indicates that concentrations of at least 0.4 per cent seem to be required. Future tests at Wooster will involve applications of Elgetol at 0.4, 0.6, and 0.8 concentrations to the same variety. The data indicate that severe leaf injury may occur, but this injury seems to be a necessary concomitant of applying sodium di-nitro-cresylate for flower and fruit removal.

Di-nitro-ortho-cyclo-hexyl-phenol and di-nitro-ortho-cresol were also quite effective in reducing fruit set when applied in oil emulsions. The first compound at the rate of 3.2 ounces to 100 gallons appeared to be more concentrated than necessary with the apple varieties involved. Gardner, Merrill, and Petering (1) employed this material at 2.4 ounces to 100 gallons of oil emulsion with somewhat less fruit removal. Further work with the chemical will involve tests with weaker concentrations than those reported in this paper. Di-nitro-ortho-cresol at the rate of 1.6 ounces to 100 gallons resulted in some thinning but in general was not quite toxic enough. Further work employing this chemical will involve concentrations of about the same range as those to be used with di-nitro-ortho-cyclo-hexyl-phenol. Whether these chemicals applied for the purpose of removing flowers will have approximately the same effectiveness at equivalent concentrations is not known at present.

Obviously, application of these materials should be made as soon as the trees have reached full bloom. Yet in these tests, much killing of opened and unopened flowers resulted from pedicel injury, although injury to the style of open flowers was also a common result of the spray application. Despite the reduction in fruit set resulting from these effects, the ultimate drop was influenced by leaf injury, which appeared to limit the amount of food available for the developing fruits during the June drop period.

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Experiences with Bloom Sprays of Elgetol for Thinning Apples[1]

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A DISCUSSION of the potential value of caustic sprays during bloom as a means of thinning apples, has been presented by Hoffman (2). Blossom sprays with Elgetol[2] have been tested each of the past three years in apple orchards of the Champlain Valley. In 1940, inconclusive results were obtained because applications were made when too many of the blossoms were not yet open. In 1941, under conditions very favorable for pollination a single rather light application of 0.1 per cent Elgetol to small trees with a power sprayer, failed to affect the yield or size of fruits of the varieties, Macoun and Northwestern Greening partly because of the relatively large number of unopened blossoms. In the variety McIntosh, where nearly all blossoms were open when the spray was applied, a reduction in set of fruit appeared to have taken place. The current years' work represented a serious effort to see whether worthwhile thinning of apples could be accomplished by such spraying under Champlain Valley conditions.

VARIETIES

Three varieties usually requiring thinning were chosen for the study. In the Champlain Valley, Wealthy exhibits a considerable degree of self-fruitfulness, invariably requires thinning and is strongly biennial. Fameuse, or Snow has similar fruiting habits but to a less degree. Northwestern Greening, although somewhat subject to setting excessively, often thins itself fairly well; usually, additional thinning is necessary to bring about the uniformly large size demanded by the market for this variety. It is much less extreme in its tendency toward alternate bearing than Wealthy and somewhat less than Fameuse.

LAYOUT AND TREATMENTS

In all varieties, matched pairs of trees were chosen, one of each pair being sprayed during bloom. Heavy applications of the material at a concentration of 0.2 per cent, were made with an orchard sprayer developing 475 pounds pressure. The sprayed Fameuse trees all received an application on May 9, when about 75 per cent of the blossoms were open. Alternate sprayed trees received a second application on May 13, when nearly all blossoms had opened and some petals were falling. One of each pair of Wealthy trees received an application on May 9 when about 40 per cent of the blossoms were open, and alternate sprayed trees received a second treatment on May 13 at the start of full bloom.

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[1] Grateful acknowledgment is made to L. A. Brinkerhoff formerly assistant in the Department of Plant Pathology, Cornell University, for help in the earlier phases of this study.

[2] A product of Standard Agricultural Chemicals, Inc., Hoboken, New Jersey, said to contain the sodium salt of dinitro-ortho-cresol and a penetrating agent.

To be sure of a thorough coverage on May 9, which was a windy day, it was necessary to use a single gun and apply about 20 gallons per tree. Some branches received more spray than necessary. The application on May 13 averaged 15 gallons per tree, which was sufficient to give a heavy coverage.

The Northwestern Greening trees received one application of 16 gallons per tree with a single gun on May 15 when they were just past full bloom, the spray knocking many petals from the trees. Although wind resulted in wastage of much of the spray, the application was a drenching one.

The weather during Wealthy and Fameuse bloom was irregular, mainly rather cool interspersed with showers for the first 6 days, and somewhat warmer during the latter few days of the blooming period, with some showers. Bees worked at least a little on no less than 9 days, but there were no exceptionally fine days for pollination. With Northwestern Greening, the bloom period was later, warmer, windier, and only 6 days in duration.

RESULTS

The main first-year results are summarized in Table I. The following comments deal with points not included or not adequately covered in the table.

TABLE I—INFLUENCE OF ELGETOL SPRAYS DURING BLOOM ON THE PERFORMANCE OF PAIRED APPLE TREES (1942)

Variety, Age, and Vigor of Trees	Number of Sprays	Number of Trees	Mean Yield (Bushels)	Mean Number Fruits Per Box¶	Mean Terminal Growth (Inches)	Mean Number Seeds Per Fruit	Per Cent Fruits With Water-core
Fameuse *About 30* Medium vigor	1	5	19.1*	154*	—	—	—
	0	5	30.6	169	—	—	—
	2	4	8.1†	135†	8.37	3.83*	28.3†
	0	4	21.2	177	5.11	5.21	5.5
Wealthy *About 30* Medium to low vigor	1	4	14±§	131	—	—	—
	0	4	14±§	163	—	—	—
	2	5	4±§	78†	5.10‡	—	—
	0	5	14±§	153	3.35	—	—
Northwestern Greening Age—11 High vigor	1	6	1.4†	70†	11.20	—	—
	0	6	8.4	124	10.29	—	—

*Difference significant by analysis of variance with odds greater than 19:1.

†Difference significant with odds greater than 99:1.

‡Significant with odds greater than 19:1 when growth of each tree is expressed as a percentage of its growth in 1941. Just lacks significance when calculated as inches of growth, disregarding 1941 growth. The Wealthy check trees grew 28 per cent less than in 1941, while the twice-sprayed trees grew 11 per cent more.

§Estimate, since some fruits were spot picked before investigators were notified.

¶1⅛ bushel box, level-full of loose apples.

Effects on Fruits:—The failure of a single spray to cause an observable difference in the yield of Wealthy was probably due to the large proportion of unopened buds (60 per cent) when the spray went on.

Despite the excessive thinning brought about by two sprays in Fameuse, the fruits were not materially above the most desirable commercial size, averaging about 2⅞ inches in diameter. However, in Wealthy, the fruits from twice-sprayed trees were excessively large, green, coarse and in many cases, affected by stippen. The drop from these trees was heavy. These same defects often are noted in Wealthy during the "off" year, if a few fruits are borne. In Northwestern Greening, many of the fruits on once-sprayed trees were above 4 inches in diameter, which is too large from a commercial viewpoint. The fruits on unsprayed trees averaged about 2¾ inches and included some below 2½ inches. The drop averaged 12 per cent of the crop for the sprayed Northwestern Greening trees against 6 per cent for the unsprayed.

In Fameuse and Northwestern Greening, no hand-thinning was done, but in Wealthy, the grower hand-thinned those trees where he deemed it necessary, on July 23, about 6 weeks before the beginning of spot-picking. He spent an average of 29 minutes per tree thinning once-sprayed trees against 44 minutes for the corresponding checks. He spent no time thinning the twice-sprayed Wealthy trees, against 42 minutes per tree for the corresponding checks.

The reduction in number of seeds per apple on the twice-sprayed Fameuse trees, indicates that the treatment was even more effective in preventing fertilization than is shown by the yield and fruit-count data. A striking feature of the twice-sprayed Fameuse trees was the "sheep-nose" shape of many of the fruits, which, in form, resembled those of the Black Gilliflower.

On seven Fameuse trees with appreciable amounts of watercore, the affected fruits averaged 5.26 seeds, whereas the unaffected averaged 4.14, the difference being significant by odds greater than 99:1. Watercore in this variety often is associated with allowing the fruits to remain on the trees too long. In severe cases, it sometimes is followed by browning of the affected flesh during storage, so its greater prevalence on the twice-sprayed Fameuse may be of some importance.

Effects on Trees:—On May 13, four days after the first application on Fameuse and Wealthy, only a trace of foliage injury was noted, but there was much "scorching" of petals and some withering of pistils and stamens; the latter effect previously was observed by others (1). A Duchess tree similarly sprayed on May 9, showed appreciable leaf-scorching. Following the second application to certain Fameuse and Wealthy trees on May 13 there were three very windy days with maximum temperatures of 86 degrees F, 84 degrees F, and 75 degrees F, respectively. By May 19, foliage injury on twice-sprayed Wealthy and Fameuse trees was severe, nearly all of the leaf-surface having been killed on some of the weaker Wealthy spurs; a few of these never leafed out again. There was more or less leaf-distortion resembling that associated with lime-sulfur injury. The complete blossom including the pedicel, was killed in many instances. While the injury was much worse with two sprays, it looked serious for a time, even where just one had been applied, especially on the weaker trees. MacDaniels and Hoffman (3) mentioned the tendency toward drastic results on trees of low vigor. The injury from one spray on Northwestern Greening appeared about as severe as that from two sprays on other varieties. Evidently Northwestern Greening is especially sensitive to this treatment, and perhaps the warm windy weather during and just after the application increased the injury.

Soon, new leaves commenced to develop, and by the middle of June, the more vigorous of the twice-sprayed trees had the most luxuriant appearance of any in the orchards. When the 15 pairs of trees that showed a sharp reduction in yield from bloom sprays are considered together, the terminal growth is significantly greater on the sprayed trees.

SUMMARY AND CONCLUSIONS

In this year's experiments with a long blooming period, Fameuse and Wealthy were thinned too little by one spray and too much by two. Northwestern Greening was thinned excessively by one spray applied just after full bloom. Excessive thinning had some beneficial, and some adverse effects on the character of the fruits. The extent to which this year's reduction in crop will be offset by next year's production, remains to be seen. Greater dilution and lighter spraying with a boom instead of a single gun, doubtless would bring about less drastic results. Since the weather, the population of pollinating insects, the availability of pollen of suitable sorts, the percentage of spurs blooming, the vigor of the tree and other factors affect fruit-set, one can hardly expect to thin fruit to precisely the desired extent by bloom sprays. The concentration of the spray and the number of applications will have to be varied according to variety, bloom, tree-vigor and weather. Even so, bloom sprays may serve to get the job done when hand-thinning would be impossible. While the cost of the spray treatment may be less than that of hand-thinning, its chief potential value probably lies in the fact that it may achieve thinning very early over the entire orchard.

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Effects of Branch Ringing on Biennial Bearing of York and Golden Delicious Apples[1]

By A. E. Murneek, *University of Missouri, Columbia, Mo.*

IN another paper it was pointed out that blossom removal by caustic sprays in the "on" year of biennially bearing varieties of apples, though possible, does not always assure full bloom and ample fruiting in the following "off" year (5). The primary objectives of the use of such sprays is the destruction of flowers, that usually, but not necessarily, is followed by initiation of flower buds. The present paper deals with another orchard practice, which, when executed shortly after the bloom is killed, will make the formation of flower buds more certain in the "on" year and thus give a greater assurance of a crop in the "off" year.

Ringing of the trunk or branches is an operation occasionally resorted to by growers to induce flowering in trees that are reluctant to come into bearing. Obviously this practice would not be satisfactory for this purpose in the "on" year of heavily bearing trees, for it will have a tendency to increase the fruit set excessively and make flower bud formation still less likely (3, 4). It might be of value, though, if the crop is light (high leaf-fruit ratio, 2), which would be difficult to ascertain, however, early in the season. But when fruit setting is prevented by destruction of the blossoms then bark ringing becomes an effective procedure for induction of flower buds, as the experimental evidence presented here testifies. The two operations go together in tandem sequence.

Results of the 1939 Experiments

Trees on which these experiments were made were 17 years old, alternate (Golden Delicious) or irregular (York) in bearing and variable, though mostly low in vegetative vigor. The flowering and fruit setting performance of these and similar trees in the orchard, for 1938 to 1942, are presented in Table I. It will be observed that the Yorks, though blooming heavily in the two "on" years, 1939 and 1941, set practically no fruit, for reasons not quite clear but possibly due to subnormal vigor.

TABLE I—Flowering and Fruit Setting Performance of York and Golden Delicious Apple Trees in Experimental Orchard

Year	York	Golden Delicious
1938 "Off" year	No bloom	No bloom
1939 "On" year	Bloom but no fruit set	Bloom and heavy fruit set
1940 "Off" year	No bloom	No bloom
1941 "On" year	Bloom but no fruit set	Bloom and heavy fruit set
1942 "Off" year	Bloom and heavy fruit set	No bloom

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[1] Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 886.

Fourteen days after the bloom had been killed completely with creosote oil, paired branches were selected on 12 York and 8 Golden Delicious trees. One of each pair was ringed. This was done according to standardized procedure described elsewhere (3). The comparative results in terms of flower and fruit production in the following years (1940 to 1942) are presented in Table II.

TABLE II—EFFECTS OF BRANCH RINGING IN CONJUNCTION WITH BLOSSOM REMOVAL BY CAUSTIC SPRAYS ON FLOWERING AND FRUITING OF BRANCHES OF YORK AND GOLDEN DELICIOUS TREES

Number of Branches	Treatment 1939 ("On Year")	1940 ("Off" Year)		1941 ("On" Year)		1942 ("Off" Year)	
		Bloom	Yield (Bu Per 10 Branches)	Bloom	Yield (Bu Per 10 Branches)	Bloom	Yield (Bu Per 10 Branches)
				*York**			
12	Bloom killed and branch ringed	Heavy to very heavy	Very heavy, 15.6 bushels	None	None, 0 bushel	Very heavy	Very heavy, 13.2 bushels
12	Bloom killed	None to very light	None to very light, 1.8 bushels	Very heavy	None to very light, 0.4 bushels	Very heavy	Very heavy, 13.0 bushels
				Golden Delicious†			
8	Bloom killed and branch ringed	Heavy	Heavy, 16.0 bushels	Light to medium	Light, 4.1 bushels	Very heavy	Very heavy, 23.8 bushels
8	Bloom killed	Light to medium	Light to medium 7.4 bushels	Very heavy	Heavy, 19.6 bushels	Light	Light, 7.1 bushels

*Age of trees (1939), 17 years; alternate to irregular bearing; closely planted on light soil.
†Age of trees (1939), 17 years; alternate bearing; planted closely on light soil; low vegetative vigor.

An inspection of the records will show that, while destruction of the flowers in the "on" year resulted, on the average, in only a light bloom and very light (York) crop to a medium (Golden Delicious) crop in the following "off" year (1940), the ringed branches invariably had a heavy to a very heavy bloom and yield. In succeeding years there was an alternation in fruit production of both the deflorated and deflorated-ringed branches of the Golden Delicious variety, but a more uniform behavior of those of York. Despite these varietal differences, the ringed branches produced far more fruit in the two "off" years (1940 and 1942) than the branches which had received only the spray treatment, that is, *York:* sprayed and ringed, 28.8 bushels; sprayed, 14.8 bushels. *Golden Delicious:* sprayed and ringed, 39.8 bushels; sprayed, 14.5 bushels. Evidently, in addition to the use of caustic sprays, branch ringing had a marked supplementary effect on induction of flower buds in the "on" year on these biennially bearing apple trees. It is probable that trunk ringing or scoring, executed with due precaution, may be of practical value as an additional orchard operation for the promotion of fruit production in the "off" year, when the bloom is destroyed by a caustic spray in the preceding "on" year.

RINGING OF FRUITING BRANCHES IN THE "ON" YEAR

In order to learn what possible effect branch ringing might have when no caustic sprays are used in the "on" year, four vigorous Golden Delicious trees in full bearing were selected for the test. Twelve paired branches were chosen for this purpose, the fruit on which had been thinned heavily. Six of them were ringed on June 6, 41 days after full bloom. The results, given in Table III, show that the ringed branches produced approximately five times as many flower clusters and four times as much fruit as the nonringed ones in the succeeding "off" year. When other branches were ringed on somewhat similar bearing Golden Delicious trees on June 27, 64 days after full bloom, no flower buds were formed. Evidently the treatment was too late.

TABLE III—EFFECTS OF RINGING BRANCHES OF BEARING GOLDEN DELICIOUS TREES* IN THE "ON" YEAR (TIME OF TREATMENT JUNE 6, 41 DAYS AFTER FULL BLOOM)

1939 ("On" Year)	1940 ("Off" Year)		
Number of Branches and Treatment	Number Flower Clusters	Number Fruit Set	Yield (Bu)
6 ringed	1,289	1,166	7.5
6 not ringed	259	311	1.7

*Trees 17 years old; vigorous; fruit thinned in 1939, before June 6.

It is very probable that weaker trees or trees whose fruit had not been thinned heavily may not respond to branch ringing in the "on" year, even when it is performed at the desirable time. That vigor is an important factor controlling the time of flower bud induction in the apple has been emphasized in other investigations (1, 2). Additional evidence on this point was obtained from a study of the relation of time of defloration or defruiting on flower bud formation in heavily bearing non-thinned Golden Delicious trees (Table IV). Flower bud initiation, as a result of complete removal of the bloom or the fruit, was induced in the "on" year as late as June 8 (43 days after full bloom) on a vigorous tree, but not later than May 16 (20 days after full bloom) on an adjoining less vigorous one,

TABLE IV—RELATION OF TIME OF FLOWER OR FRUIT REMOVAL TO FLOWER BUD INDUCTION IN GOLDEN DELICIOUS APPLE TREES*

1939 ("On" Year)	Number of Flower Clusters in 1940 ("Off" Year)	
Time of Treatment	Vigorous Tree	Moderately Vigorous Tree
Apr 26, full bloom	496	394
May 6, first drop in progress	454	167
May 16, fruit 1.2 cm in diameter	285	338
May 27, fruit 2 cm in diameter	278	76
June 8, fruit 3 cm in diameter	209	53
Control (no treatment)	8	7

*Trees 17 years old, biennial bearing.

SUMMARY

In order to modify biennial bearing of apple trees, the desirable effects from use of a caustic spray to kill the bloom in the "on" year may be augmented and made more certain by branch ringing. This operation should be performed 2 weeks or possibly a little later after the flowers have been destroyed by spraying. As a result of the two treatments, spraying and ringing, more fruit was produced in the "off" year in comparison to the use of a caustic spray alone. Branch ringing of bearing trees in the "on" year (with no bloom killing) may be of possible value if the fruit has been thinned heavily, the trees are vigorous and the operation performed at the right time.

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The Effect of Certain Chemicals on the Fruit Set of the Apple

By G. W. SCHNEIDER and J. V. ENZIE, *New Mexico State College, State College, N. M.*

THE use of various chemicals such as tar oil distillates, Elgetol and di-nitro-ortho-cyclo-hexyl-phenol applied as a spray, to reduce and prevent fruit set of the "on" year apple crop has been rather widely tested. Other materials have also been tried, but as yet, the results are not sufficiently complete or satisfactory to warrant their use as a common commercial practice. Magness, Batjer, and Harley (4) demonstrated the possibilities of using caustic sprays in controlling biennial bearing. Hoffman (2), MacDaniels and Hoffman (3), and Gardner *et al.* (1), have also reported positive results from the application of certain spray materials.

The biennial bearing problem is as important in New Mexico as in other areas of the United States, for vigorous Delicious and Gano trees in the College orchard were definitely biennial when 15 years old. Since biennial bearing is a common problem, a series of experiments was started in an effort to secure some means of reducing or controlling this condition.

All apple varieties now being grown in the College orchard tend to drop their fruit more or less continuously from the "June drop" to harvest. In view of this, it was deemed advisable to determine the extent that these materials influenced this drop. Thus records were made of the number of fruits on the tree at harvest.

MATERIALS AND METHODS

For these experiments, 16-year-old trees of the Delicious, Gano, and Arkansas Black varieties were used. Limbs rather than entire trees were treated or left as checks. The materials in each group of tests were applied to the same trees. The limbs were selected for uniformity of size, number of blossoming points, and similarity of position so the limbs would be as similar and comparable as possible. A large percentage of the potential flowering points flowered in 1942, which was the "on" year for alternate bearing varieties.

The materials tested included: Liquid lime sulfur followed by summer oil; Elgetol; Reico; Bordeaux; Bordeaux and summer oil; di-nitro-ortho-cyclo-hexyl-phenol; di-nitro-ortho-cresol; naphthalene acetic acid; naphthalene acetamide; indoleacetic acid; and two commercial growth products known as Staymone and Hormex. They were tested at various strengths on flowers at different stages of opening. The concentrations of the sprays used refer to the amount of the actual chemical by weight without regard to fillers or carriers, except that the Elgetol was made up on a volume basis using the prepared material.

The number of flowering points of the treated and check limbs was recorded in full bloom. The count to determine set was made after the June drop, and the percentage of flowering points that set fruit was calculated from these figures. The limbs were harvested individually, and a record was made of the number of flowering points which matured fruit. This number was divided by the total number of flowering points to determine the percentage of points maturing fruit. The data were analyzed by the variance method of Snedecor (5). The data presented are for 1 year and should be regarded as a progress report. The subsequent blossoming and fruiting behavior of these experimental limbs will be recorded.

RESULTS

Spray Materials on Delicious:—Since the combination of liquid lime sulfur and summer oil has been found to injure fruit (6), it was thought it might have a tendency to reduce fruit set if applied before the blossoms had set. Preliminary tests made in the greenhouse showed that a concentration of 1 per cent liquid lime sulfur applied in the pre-pink stage followed by an application of 1 per cent summer oil spray 7 days later had a definite toxic effect on both flowers and foliage. These materials were then tested in the orchard at two strengths. One was a 0.5 per cent liquid lime sulfur spray, applied in the green bud to pink stage, followed by a similar concentration of summer oil 2 days later; the other was a 1 per cent concentration of each material applied at the same time as the above. The results of this test are shown as A and B in Table I. As may be observed in Table I, the spray had no significant effect on the percentage of flowering points that set fruit or on the percentage of points that matured fruits. The treated limbs showed no injury to the leaves or spurs as a result of these applications.

A single application of Reico, a tar oil product, was made at concentrations of 0.8 per cent and 1.6 per cent when the flowers were in the pre-pink to pink stage of opening. It will be noted, in Table I under E and F, that the 0.8 per cent concentration reduced the set significantly and the 1.6 per cent concentration caused a still greater reduction in set. The concentrations had the same general effect on the percentage of flowering points that matured fruit, for the 0.8 per cent concentration caused a significant reduction and the 1.6 per cent spray reduced it still more. The injury to leaves and spurs from the single application of the 0.8 per cent concentration was not particularly serious; however, the application of the 1.6 per cent material caused too much injury to be a desirable means of reducing set.

Since Bordeaux sprays are known to have fungicidal value, and also tend to increase transpiration, it was thought that some combination of Bordeaux sprays might reduce set by desiccation under arid conditions. The following concentrations of Bordeaux were used separately: 4–6–100, 6–6–100, and 6–6–100 plus 1 per cent summer oil. Two applications of each strength were made for each treatment. The first application was made when the central flower was open and the second in full bloom. These applications had no significant effect on the set of Delicious flowers, as may be seen under G, H, and I in Table I. Likewise, they had no significant effect on the percentage of flowering points that matured fruit. The Bordeaux sprays or a combination of Bordeaux and summer oil caused no visible injury to the spurs or foliage of the tree.

TABLE I—THE RESULTS OF SPRAYING DELICIOUS FLOWERING POINTS WITH CERTAIN CHEMICALS

Treatment*	Number of Limbs	Stage of Opening and Number of Applications	Ave Per Cent of Flowering Points Setting Fruit	Difference Necessary for Significance at 5 Per Cent Level	Injury to		Ave Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
					Leaves	Spurs		
A	5	First application at green bud to pre-pink Second at pink stage	43.2	———	None	None	20.2	———
B	5		38.8	———	None	None	15.0	———
CK	5		48.9	Not significant	None	None	19.5	Not significant
E	5	One application at late pink to pre-pink	17.9	———	Moderate	Very few killed	10.8	———
F	5		12.8	———	Severe	Some killed	10.1	———
CK	5		29.0	8.07	None	None	18.4	5.8
G	5	First application when central flowers open. Second application at full bloom	35.0	———	None	None	27.0	———
H	5		43.7	———	None	None	35.9	———
I	5		40.2	———	None	None	30.5	———
CK	5		47.0	Not significant	None	None	37.1	Not significant
J	5	One application at late pink stage	28.7	———	Very slight	None	19.9	———
K	5		45.5	———	Moderate	None	39.6	———
CK	5		67.8	17.9	None	None	52.4	18.5
N	5	One application at full bloom	6.6	———	Very slight burning, severe twisting	None	2.3	———
O	5		3.3	———	Mod. burning, very severe twisting	None	0.0	
T	5		59.5	—	None	None	24.9	—
CK	5		63.6	23.5	None	None	32.4	11.8

*Key to spray materials:

(A) 0.5 per cent liquid lime sulfur followed by 0.5 per cent summer oil.
(B) 1.0 per cent liquid lime sulfur followed by 1.0 per cent summer oil.
(E) 0.8 per cent concentration of the tar oil product, Reico.
(F) 1.6 per cent concentration of the tar oil product, Reico.
(G) 4–6–100 Bordeaux (4 pounds copper sulfate).
(H) 6–6–100 Bordeaux.
(I) 6–6–100 Bordeaux plus 1 per cent summer oil.
(J) 0.15 per cent concentration of di-nitro-ortho-cycle-hexyl-phenol.
(K) 0.20 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(N) 0.01 per cent concentration of naphthalene acetic acid.
(O) 0.03 per cent concentration of naphthalene acetic acid.
(T) 0.01 per cent concentration of indole acetic acid.

One application of di-nitro-ortho-cyclo-hexyl-phenol spray of two concentrations was tested. This material was applied in the pink stage of opening. As may be seen in Table I under J and K, the spray of 0.15 per cent concentration caused a significant reduction in set; in fact, the reduction in set was greater when a 0.15 per cent concentration was used than when a 0.2 per cent concentration was used. The writers have no explanation for this discrepancy; however, the same relationship was maintained until harvest when the reduction in percentage of blossoming points maturing fruit, caused by 0.15 per cent spray, was greater than that caused by the 0.2 per cent concentration. The visible injury to spurs and leaves as a result of applying this material was not serious.

The effect of single applications of some of the so-called plant hormones was tested by applying naphthalene acetic acid, at 0.01 per cent concentration and 0.03 per cent concentration at full bloom. A 0.01 per cent solution of indoleacetic acid applied at full bloom was included in this test group. The single application of the two strengths of naphthalene acetic acid caused a highly significant reduction in fruit set. The set was 6.6 per cent in the case of the stronger concentration, 3.3 for the weaker and 63.6 for the untreated limbs. The indole acetic acid had no significant effect on fruit set. As shown under N, O, and T in Table I, these materials had the same effect on the percentage of flowering points that matured fruit as they had on per cent set. The 0.01 per cent naphthalene acetic acid caused very slight burning of the leaves, with considerable leaf deformity being conspicuous. As may be expected, the 0.03 per cent spray caused more severe burning and leaf deformity than did the weaker concentration. Neither of the above concentrations caused visible spur injury. The indoleacetic acid caused no visible spur or leaf injury.

Spray Materials on Gano:—The combination of liquid lime sulfur

TABLE II—THE RESULTS OF SPRAYING GANO FLOWERING POINTS WITH CERTAIN CHEMICALS

Treatment*	Number of Limbs	Stage of Opening and Number of Applications	Ave Per Cent of Flowering Points Setting	Difference Necessary for Significance at 5 Per Cent Level	Injury to		Ave Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
					Leaves	Spurs		
A	4	Liquid lime sulfur at pre-pink—oil at pink and opening	60.2	———	None	None	40.4	———
B	4		60.1	———	None	None	43.0	———
CK	4		57.1	Not significant	None	None	52.0	Not significant
E	5	One application at pre-pink to very early pink	53.4	———	Moderate	Very few killed	44.7	———
F	5		60.4	———	Severe	Some killed	46.5	———
CK	5		91.1	17.1	None	None	66.9	8.3
J	4	One application at pink to a few flowers open	68.7	———	Very slight	None	48.9	———
K	4		57.5	———	Moderate	None	42.2	———
CK	4		78.9	Not significant	None	None	50.7	Not significant
N	5	One application at full-bloom	5.9	———	Very slight burning, considerable twisting	None	1.6	———
O	5	———	2.3	———	Very severe	None	2.0	———
T	5	———	56.1	———	None	None	35.4	———
CK	5	———	48.8	16.8	None	None	26.2	8.9

*Key to spray materials:

(A) 0.5 per cent liquid lime sulfur followed by 0.5 per cent summer oil.
(B) 1.0 per cent liquid lime sulfur followed by 1.0 per cent summer oil.
(E) 0.6 per cent concentration of the tar oil product, Reico.
(F) 1.2 per cent concentration of the tar oil product, Reico.
(J) 0.15 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(K) 0.20 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(N) 0.01 per cent concentration of naphthalene acetic acid.
(O) 0.03 per cent concentration of naphthalene acetic acid.
(T) 0.01 per cent concentration of indole acetic acid.

followed by summer oil was also tested on the Gano variety. The combinations and concentrations of these materials was the same as for Delicious, except that the interval between the lime sulfur and summer oil applications was increased to 5 days. The results of this test are shown as A and B in Table II. On the Gano, as on the Delicious, there was no significant reduction in fruit set or in the percentage of flowering points that matured fruit. The above sprays caused no visible injury.

The effect of one application of the tar oil product, Reico, used at 0.6 per cent concentration and 1.2 per cent concentration, was tested. An application of each strength was made at the late pre-pink to very early pink stage of opening. As shown under E and F in Table II, the application of these concentrations caused a significant reduction in set. The 0.6 per cent spray caused a moderate amount of leaf injury and killed a limited number of spurs; however, the 1.2 per cent spray caused severe leaf injury and killed more spurs. As on Delicious, the more concentrated material caused more injury than is desirable for this type of spray, and in spite of this rather severe injury to leaves and spurs, many of the flowers developed into fruit. Although an analysis of the data showed a significant difference in set between the spray treatments and the untreated limbs, the actual reduction in set on the treated limbs was not enough to eliminate the need for further thinning.

One application of a 0.15 per cent solution of di-nitro-ortho-cyclohexyl-phenol applied in the late pink stage of opening had no significant effect on the percentage of flowering points that set fruit. The 0.2 per cent solution also failed to cause a significant reduction in set. Treatments J and K in Table II show that neither concentration significantly affected the percentage of flowering points that matured fruit. The 0.15 per cent and the 0.20 per cent concentration caused a small amount of spur and foliage injury.

The effect of the growth substances, naphthalene acetic acid and indole acetic acid, was also tested on Gano. A 0.01 and a 0.03 per cent solution of naphthalene acetic acid and a 0.01 per cent solution of indole acetic acid were applied. Both strengths of naphthalene acetic acid caused a highly significant reduction in fruit set and the percentage of flowering points that matured fruit. The indole acetic acid treatment failed to influence the set but matured a significantly higher percentage of fruit than did the check. These data are given in Table II as N, O, and T. The injury from the naphthalene acetic acid was confined to the foliage, which was slightly burned and considerably deformed by the 0.01 per cent concentration. The stronger concentration caused more foliage injury but no visible spur injury. The indole acetic acid showed neither leaf nor spur injury.

Spray Materials on Arkansas Black:—A 0.15 per cent solution and a 0.30 per cent solution of Elgetol was used, a single application being made when the flowers were in the pre-pink stage of opening. Neither of the above strengths had a significant effect on the percentage of flowering points that set fruit nor on the per cent of points that matured fruit. The effect of each concentration is shown under C and D in

TABLE III—THE RESULTS OF SPRAYING ARKANSAS BLACK FLOWERING POINTS WITH CERTAIN CHEMICALS

Treatment*	Number of Limbs	Stage of Opening and Number of Applications	Ave Per Cent of Flowering Points Setting	Difference Required for Significance at 5 Per Cent Level	Injury to		Ave Per Cent of Flowering Points Maturing Fruits	Difference Required for Significance at 5 Per Cent Level
					Leaves	Spurs		
C	5	One application at pre-pink to pink	30.4	——	Very slight	Very slight	24.8	——
D	5		41.7	——	Slight	Slight	28.9	——
CK	5		41.8	Not significant	None	None	26.3	Not significant
E	5	One application at pink	1.2	——	Slight	Slight	0.5	——
F	5		3.0	——	Moderate	Moderate	1.9	——
CK	5		44.8	15.7	None	None	38.9	13.4
H	5	First application when central flower open, second at full bloom	22.2	——	None	None	20.7	——
I	5		26.1	——	None	None	22.0	——
CK	5		37.4	Not significant	None	None	30.2	Not significant
J	5	One application at pink	18.7	——	Moderate	Moderate	16.8	——
K	5		7.8	——	Moderate	Moderate	5.3	——
CK	5		45.3	21.9	None	None	30.7	17 5
L	5	One application pre-pink to pink	15.1	——	Very slight	Very slight	10.8	——
M	5		7.0	——	Slight	Slight	5.6	——
CK	5		40.2	14.5	None	None	33.4	13.1
N	10	One application at full bloom	0.1	——	Moderate twist	None	0.1	——
O	10		0.0	——	Very severe	None	0.0	——
P	10	——————	4.2	——	None	None	1.5	——
Q	10	——————	3.7	——	Slight	None	2.2	——
CK	10	——————	24.6	6.9	None	None	7.2	3.9
R	10	One application at full bloom	19.4	——	None	None	14.8	——
S	10		6.3	——	None	None	4.2	——
Z	10		27.8	——	None	None	20.4	——
CK	10		28.2	10.9	None	None	21.4	11.1

*Key to spray materials:
(C) 0.15 per cent concentration of Elgetol.
(D) 0.30 per cent concentration of Elgetol.
(E) 0.6 per cent concentration of Reico.
(F) 1.0 per cent concentration of Reico.
(H) 6-3-100 Bordeaux (6 pounds copper sulfate).
(I) 6-3-100 Bordeaux plus 1½ per cent summer oil.
(J) 0.2 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(K) 0.3 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(L) 0.15 per cent concentration of di-nitro-ortho-cresol.
(M) 0.25 per cent concentration of di-nitro-ortho-cresol.
(N) 0.01 per cent concentration of naphthalene acetic acid.
(O) 0.03 per cent concentration of naphthalene acetic acid.
(P) 0.01 per cent concentration of naphthalene acetamide.
(Q) 0.03 per cent concentration of naphthalene acetamide.
(R) 0.001 per cent concentration of naphthalene acetic acid (Hormex).
(S) 0.002 per cent concentration of naphthalene acetic acid (Hormex).
(Z) Full strength Staymone dust.

Table III. As may be seen in Table III, the amount of injury from the Elgetol sprays was of little importance.

Reico was tested on Arkansas Black limbs at the following strengths: 0.6 per cent concentration and 1.0 per cent concentration. One application was applied when the blossoms were in the pink stage of opening. The results of this test are shown as E and F in Table III. Both concentrations caused a highly significant reduction in both fruit set and the percentage of flowering points that matured fruit. This marked reduction in the crop was brought about with but slight leaf and spur injury from the 0.6 per cent concentration and a moderate amount from the stronger spray.

The Bordeaux formula was changed to a 6–3–100 Bordeaux for treatment H and a 6–3–100 Bordeaux plus 1½ per cent summer oil for treatment I in Table III. Two applications were made, the first when the central flower was open and the second when the tree was in full bloom. As shown in Table III, there was no significant reduction in per cent set or final matured crop on the treated limbs. These sprays caused no visible spur or foliage injury.

The effect of di-nitro-ortho-cyclo-hexyl-phenol spray was also tested on Arkansas Black. A single application of a 0.2 per cent solution was made when the flowers were in the pink stage of opening. A similar and comparable application of a 0.3 per cent spray was also made. The 0.2 per cent spray significantly reduced set of flowering points from 45.3 per cent (the check) to 18.7 per cent, and the 0.3 per cent solution caused a still greater reduction in set to 7.8 per cent of the flowering points. Treatments J and K in Table III show, further, that the above sprays had the same general effect on the percentage of flowering points that matured fruit, for each caused a reduction in the number of points that matured fruit. These concentrations of di-nitro-ortho-cyclo-hexyl-phenol caused moderate visible leaf and spur injury.

Di-nitro-ortho-cresol was applied to Arkansas Black blossoms when they were in the pre-pink to pink stage of opening. In this test a 0.15 per cent concentration and a 0.25 per cent concentration were applied to separate limbs at the above stage of opening. Both concentrations caused highly significant reductions in per cent set, as shown in Table III as L and M. These materials had a similar affect on the percentage of flowering points that matured fruit. This material caused only a very slight amount of injury when used at the 0.15 per cent concentration. Only slightly more injury to foliage and spurs was visible when the stronger spray was applied.

The materials naphthalene acetic acid and naphthalene acetamide were each tested at two strengths on the Arkansas Black variety. The 0.01 per cent and 0.03 per cent naphthalene acetic acid spray are represented as N and O in Table III, respectively, and the same concentrations of naphthalene acetamide are shown as P and Q in the table. Each of these materials was applied to individual limbs when the flowers were in full bloom. Each, at both concentrations, caused a significant reduction in fruit set and in the percentage of flowering points that matured fruit. However, there was considerable difference in their effect on the foliage of the tree. The 0.01 per cent concentration of naphthalene acetic acid caused considerable leaf deformity, while the .03 per cent spray caused still more deformity and a very small amount of burning. The leaves also had a distinct grayish cast rather than the dark green color of the checks. The weaker concentration of naphthalene acetamide caused no appreciable amount of leaf injury. The 0.03 per cent spray caused some visible leaf deformity, less pronounced, however, than that caused by the 0.01 per cent naphthalene acetic acid spray. Neither spray material nor concentration of that material caused visible spur injury.

The Hormex material tested on Arkansas Black contained naphthalene acetic acid plus another ingredient. It was used at the concentration of 0.001 per cent naphthalene acetic acid and 0.002 per cent naphthalene acetic acid. The product Staymone, containing levulinic acid as part of the active ingredient, was applied as a dust with no filler or carrier added. Those materials were applied when the flowers were in full bloom and are shown as treatments R, S, and Z in Table III. The 0.001 per cent strength of naphthalene acetic acid (Hormex) caused no significant effect on per cent set or on the percentage of flowering points that matured fruit. The 0.002 per cent spray of the same product caused a reduction in set from 28.2 per cent (the check) to 6.3 per cent, which was highly significant. It also had the same comparative effect on the percentage of flowering points that matured fruit. The Staymone dust had no significant effect on set or amount of fruit matured. These treatments showed no visible injury to foliage or spurs.

The sprays that appeared to be most promising in the limb tests on Delicious and Gano were tested on entire scaffold limbs of Arkansas Black. In this series six scaffold limbs on each of five trees were selected and each scaffold received one of the treatments listed below. A representative limb on each scaffold was selected and counted for the data given in Table IV. Treatment A consisted of one application of a 0.20 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol applied in full bloom. Treatment C was one application of di-nitro-ortho-cresol used at a strength of 0.25 per cent and applied in late pre-pink stage of blossoming. Treatment D was one application of 1.0 per cent concentration of Reico applied in the pre-pink stage. Treatment B consisted of one application of a 0.25 per cent concentration of di-nitro-

TABLE IV—THE RESULTS OF SPRAYING THE FLOWERING POINTS OF ENTIRE SCAFFOLDS OF ARKANSAS BLACK WITH CERTAIN CHEMICALS

Treatment*	Number of Limbs	Stage of Opening and Number of Applications	Ave Per Cent of Flowering Points Setting	Difference Necessary for Significance at 5 Per Cent Level	Injury to		Ave Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
					Leaves	Spurs		
A	5	One application just before full bloom	4.9	——	Very severe	Moderate	2.5	——
B	5	One application at pre-pink to pink	10.9	——	Moderate	Moderate	5.5	——
C	5	One application at pre-pink to pink	0.7	——	Slight	Very severe	0.7	——
D	5	One application at pre-pink to pink	5.0	——	Slight	Moderate	3.0	——
E	5	One application when few flowers open, second at full bloom	2.7	——	Very slight	None	1.5	——
CK	5	——————	36.4	8.3	None	None	15.9	7.1

*Key to spray materials:
(A) 0.20 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(B) 0.25 per cent concentration of di-nitro-ortho-cyclo-hexyl-phenol.
(C) 0.25 per cent concentration of di-nitro-ortho-cresol.
(D) 1.0 per cent concentration of Reico.
(E) 6–4–100 Bordeaux plus 2 per cent summer oil (6 pounds copper sulfate).

-ortho-cyclo-hexyl-phenol applied at the pre-pink stage. Treatment E was a 6–4–100 Bordeaux plus 2 per cent summer oil spray. Two applications were made, the first when the central blossoms were open and the second at full bloom. Comparable scaffold limbs were retained as checks. Each of the above treatments was effective in that they all caused a highly significant reduction in fruit set when compared with the check. There also was a highly significant reduction in the percentage of flowering points that matured fruit as a result of the application of each of the above sprays. Treatment C (di-nitro-ortho-cresol) caused the greatest reduction in both the set and size of crop; however, the injury to spurs was very severe. Two applications of the 6–4–100 Bordeaux plus 2 per cent summer oil (treatment E) caused the next greatest reduction in set and percentage of points that matured fruit. It caused the least amount of visible leaf and spur injury. In comparing the time of application and strength of di-nitro-ortho-cyclo-hexyl-phenol (treatments A and B) the 0.2 per cent concentration applied in full bloom caused more visible leaf injury than the 0.25 per cent concentration applied in the pre-pink stage. There was no appreciable difference in their effect on the spurs. The 1.0 per cent Reico spray (treatment D) was also effective in reducing set, but did not cause severe visible damage to the leaves or spurs.

SUMMARY

The spray combination of liquid lime sulfur followed by summer oil appeared to have very little if any effect on the tree or the fruit crop on Gano and Delicious trees.

Elgetol sprays on Arkansas Black limbs failed to influence the crop and did not seriously injure the foliage or tree at the concentrations used in these tests.

The tar oil product, Reico, was tested on all three varieties and on each it caused a reduction in set when used at concentrations as low as 0.6 per cent and 0.8 per cent. Higher concentrations reduced the crop more but they also caused more injury, which in most cases was severe.

The Bordeaux spray combinations were not effective in most cases, for the set and crop were not reduced by two applications of most of the various Bordeaux combinations. The one exception was the combination of 6–4–100 Bordeaux plus 2 per cent summer oil applied to Arkansas Black. This gave a definite reduction in set and crop. The two applications of the combination spray did not cause visible leaf or spur injury.

The tests using di-nitro-ortho-cyclo-hexyl-phenol indicate that the per cent set and the crop of Delicious and Arkansas Black were definitely reduced without serious injury to the tree.

The di-nitro-ortho-cresol tests on Arkansas Black show that the material did definitely reduce the crop; however, it appeared to be rather injurious to the spurs.

Naphthalene acetic acid and naphthalene acetamide both show a definite reducing effect on fruit set and crop of all varieties tested, for 0.01 per cent spray of either material applied in full bloom nearly eliminated the crop. A 0.002 per cent spray of naphthalene acetic acid also reduced fruit set on Arkansas Black. The growth substance indole acetic acid did not affect set of Delicious or Gano apples; however, it did increase the percentage of Gano flowering points that matured fruit. Another growth substance containing levulinic acid gave no definite response.

These data are from one year's results and therefore should be regarded as a preliminary report.

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Caustic Sprays to Modify Alternate Fruit Production[1]

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SPRAYING tests for the prevention of fruit set and the control of apple production in biennially bearing varieties have been conducted for a number of years at the Missouri Fruit Experiment Station, Mountain Grove, Missouri. Of the large number of materials tried, cresylic acid at concentrations of .5 to 2 per cent and tar oil distillate at 3 per cent were found most effective when applied thoroughly in the late cluster bud stage of flower development (5). The present report is on the use of the above and other caustic sprays in experiments to modify alternate fruit production of Wealthy, Golden Delicious and York varieties of apples. With two exceptions, all the spraying was done in orchards of the Missouri Agricultural Experiment Station, Columbia, Missouri.

Preliminary tests made in 1939 on York and Golden Delicious trees showed that cresylic acid, though effective in killing of blossoms, caused uneven production of foliage and some spur injury, while the tar oils, as found on the market, were of uncertain composition. Since the most effective ingredient in tar oil is undoubtedly creosote oil,[2] a manufacturer was induced to prepare creosote oils of various "cuts" (fractions distilled at various temperatures). Some of these were found highly desirable for this purpose (3), excepting that, like other materials of this sort, they were not miscible in water. This has been corrected lately and creosote oil is obtainable in satisfactory emulsified form.[3] Several other, especially "dinitro" or "phenol" spray materials have been used recently for the purpose of flower removal (2).

EFFECTS OF BLOSSOM REMOVAL ON ALTERNATE BEARING

The 1939 Experiments:—While it is possible to prevent the fruit set either completely or partly by the use of caustic sprays of various kinds, flower production and a crop in the following year is not thereby always assured. This is especially so if the trees are of relatively low vigor and fruit production has been not only decidedly biennial but irregular (York).

When, for example, cresylic acid at 1 to 2 per cent and creosote oil at 1 to 2 per cent strength were used in the "on" year (1939) on Wealthy, Golden Delicious and York trees, the bloom was destroyed quite completely on all sprayed trees with the exception of those of the Wealthy variety. In the latter case killing of flowers was incomplete, due to a considerable amount of delayed bloom, mostly lateral and terminal. As a consequence, and contrary to expectations, there was no bloom and crop in the following "off" year (Table I).

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[1] Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 885.

[2] "Tar oil No. 1". Composition: creosote oil 63 per cent, petroleum oil 21 per cent, soap 16 per cent.

[3] Put on the market under the name of "Reico" (emulsified).

In the case of Golden Delicious and York trees, although the sprays killed all the flowers in 1939, there was no or only a light flower and fruit production in 1940 ("off" year). Moreover, in the succeeding years, the sprayed trees behaved quite similarly to unsprayed ones in alternation of fruiting (Table I). These results seem to point to the fact that, while caustic sprays may be used to prevent fruit set, this practice alone is not sufficient to induce flower bud formation in the same year. In other words, the removal of the bloom is not always followed promptly by another full set of flowers (flower buds).

TABLE I—RESULTS OF BLOSSOM REMOVAL BY CAUSTIC SPRAYS IN 1939 ON SUBSEQUENT FLOWER PRODUCTION AND FRUIT SET (1940 TO 1942) WEALTHY, GOLDEN DELICIOUS AND YORK

Treatment, 1939 ("On" Year)	1939	1940 ("Off" Year)		1941 ("On" Year)		1942 ("Off" Year)	
	Yield	Bloom	Yield	Bloom	Yield	Bloom	Yield
*Wealthy**							
Cresylic acid, 1.5 and 2.0 per cent; creosote oil, 1.5 per cent	Medium	None	None	Heavy	Heavy	None	None
Controls	Heavy	None	None	Heavy	Heavy	None	None
Golden Delicious†							
Cresylic acid, 1.0, 1.5 and 2.0 per cent; creosote oil, 1.0 and 2.0 per cent	None	Light to medium	Light to medium	Heavy	Heavy	None	None
Controls	Heavy	None	None	Heavy	Heavy	None	None
York‡							
Cresylic acid, 1.0, 1.5 and 2.0 per cent; creosote oil, 1.0 and 2 per cent	None	None to light	None to light	Heavy	None	Heavy	Heavy
Controls	None	None	None	Heavy	None	Heavy	Heavy
York§							
Cresylic acid, 1.5 per cent; creosote oil, 1.5 per cent	None	Medium to heavy	Medium	Heavy	Light	Heavy	Heavy
Controls	None	Heavy	Medium	Heavy	Light	Heavy	Heavy

*Trees 29 years old; alternate bearing; moderately vigorous.

†Trees 17 years old; alternate bearing; planted closely on light soil; low vegetative vigor.

‡Trees 17 years old; alternate to irregular bearing; planted closely on light soil; low vegetative vigor.

§Trees 16 years old; alternate to irregular bearing; vigorous.

The irregularity in crop production of the York trees needs to be emphasized. Though blooming heavily in the "on" year (1939), they did not set fruit. Flower removal, therefore, had but a moderate effect on induction of reproduction and yield of fruit in the following "off" year (1940). Because of close planting on light soil, and therefore of low vegetative vigor (see footnote ‡, Table I), the Yorks did not produce a crop for four consecutive years (1938 to 1941), during two of which there was a heavy bloom (1939 and 1941), but they yielded excessive amount of fruit in 1942, an "off" year. Similar irregularities in fruit setting of this variety have been observed in certain regions in the Central States and elsewhere (1).

With greater vigor there appears to be an improved capacity of York trees to yield fruit more frequently (see footnote §, Table I).

It would seem probable, therefore, that not only an excessive load of fruit but even of bloom on trees of this variety may lead to alternate bearing or even greater irregularities in fruit production, when they are of low vegetative vigor because of poor soil, drought, or other causes.

The 1941 Experiments:—Results of bloom killing tests in 1941 on flowering and fruiting in 1942 of Wealthy and Golden Delicious trees are given in Tables II and III. Creosote oil (CO) at .5 to 1.5 per cent, tar oil distillate (TOD) at .5 to 2 per cent and dinitro-o-cyclohexyl phenol (DNO) at .5 to 2 per cent emulsified with goulac-

TABLE II—RESULTS OF BLOSSOM REMOVAL BY CAUSTIC SPRAYS ON FLOWER PRODUCTION AND FRUIT SET THE FOLLOWING YEAR (WEALTHY AND GOLDEN DELICIOUS)

Number of Trees	Variety and Treatment, 1941 ("On" Year)	1941		1942 ("Off" Year)	
		Fruit Set Per 100 Clusters	Average Yield Per Tree (Bu)	Bloom	Yield
		Wealthy[*]			
1	DNO[‡] 2.0 per cent	1.2	2.5	Heavy	Heavy
1	DNO 1.0 per cent	5.0	3.5	Heavy	Heavy
2	CO[§] 1.5 per cent	6.7	4.2	Light	Light
3	CO 1.0 per cent	13.4	9.5	None	None
2	Controls	18.0	12.5	None	None
		Golden Delicious[†]			
1	DNO 1 per cent	0	0	Heavy	Heavy
2	TOD[‖] 2 per cent	0	0	Heavy	Heavy
2	TOD 0.8 per cent	0	0	Heavy	Heavy
4	Controls	39.6	Heavy	None	None

[*] Trees 31 years old; alternate bearing; moderately vigorous.
[†] Trees 19 years old; alternate bearing; planted closely on light soil; fair vegetative vigor.
[‡] 4.8 ounces dinitro-o-cyclohexyl phenol per gallon, emulsified with goulac-bentonite.
[§] Creosote oil, emulsified with goulac-bentonite.
[‖] Ortho tar oil distillate (94.5 per cent creosote oil), emulsified with goulac-bentonite.

TABLE III—RESULTS OF BLOSSOM REMOVAL BY CAUSTIC SPRAYS ON FLOWER PRODUCTION AND FRUIT SET THE FOLLOWING YEAR (GOLDEN DELICIOUS[*])

Number of Trees	Treatment, 1941 ("On" Year)	1941		1942 ("Off" Year)		Yield (Bu) 1941 and 1942 Per tree	Space on Branches Producing:	
		Fruit Set Per 100 Clusters	Average Yield Per Tree (Bu)	Fruit Set Per 100 Clusters	Average Yield Per Tree (Bu)		100 Flower Clusters (1941)	Had-flower-Clusters (1942)
4	DNO 2 per cent	0.4	0.2	45.5	13.2	13.4	100	51
4	DNO 1 per cent	4.6	2.1	78.6	8.4	10.5	100	24
4	DNO 0.7 per cent	2.2	3.5	92.9	12.4	15.9	100	22
4	DNO 0.5 per cent	2.1	3.5	97.3	11.1	14.6	100	13
4	TOD 2 per cent	0.0	0.0	78.8	10.4	10.4	100	35
4	TOD 1 per cent	0.3	0.6	74.4	12.8	13.4	100	36
4	TOD 0.8 per cent	1.1	1.7	80.0	17.0	18.7	100	37
4	TOD 0.5 per cent	5.0	9.1	80.1	17.2	26.3	100	31
12	CO 1.5 per cent	2.3	3.4	68.7	14.3	17.7	100	45
4	CO 1 per cent	1.0	1.7	113.3	14.8	16.5	100	27
4	CO 0.5 per cent	9.2	7.5	97.4	10.0	17.5	100	22
8	Controls	45.7	15.4	47.5	0.5	15.9	100	1

[*] Trees 22 years old; moderately vigorous to weak; almost all have "stem injury", successfully bridge grafted, however.

bentonite, were applied at late cluster bud stage when about 10 per cent of the first flowers were open. Spraying was thorough at 350 to 400 pounds pressure.

The "fruit set per 100 clusters" is based on counts of fruit present per 500 or more flower clusters on two branches of each tree. This was done after all the natural drops had occurred. "Average yields per tree", in bushels, include all fruit, whether marketable or not.

Data for 1941 and 1942, presented in Table II, show, as in the case of the 1939 spraying tests, the difficulty of killing completely the bloom on Wealthy trees of an advanced age and moderate vigor. Though spraying was very thorough at what was considered the best time, neither creosote oil at 1.0 to 1.5 per cent nor dinitro phenol at 1.0 to 2 per cent eliminated the fruit set. Contrarywise, the same materials on Golden Delicious were 100 per cent effective.

Our records show that, if the blossom kill is complete (Golden Delicious) or the flowers are destroyed to such an extent that no more than five fruit set per 100 flower clusters (Wealthy) flower bud formation may be extensive and a heavy bloom and fruit set may be expected, but not assured (York, 1939) the following year. This may happen provided the climatic conditions are favorable and the trees are in fair vegetative vigor.

In 1941 extensive tests with caustic sprays were conducted on alternate bearing Golden Delicious trees in a commercial orchard.[4] The immediate objectives were to find the most desirable concentrations of certain materials that would (a) "thin the crop" by a partial killing of the bloom and (b) more or less completely eliminate the fruit set in the "on" year. Detailed data on performance of the flowers and on yields were obtained in 1941 ("on" year) and 1942 ("off" year) Table III.

While the results are not "beautifully consistent", due chiefly to variability of the trees, they do indicate that, at .5 per cent concentration, one thorough application of the spray material reduced the crop to about half (exception DNO). At higher concentrations, up to 2 per cent, the fruit set was almost or completely eliminated. Quite independent of the extent of crop reduction in 1941, all of the sprayed trees had a good but not abnormally heavy bloom the following "off" year, while the control trees were quite devoid of blossoms. The fruit yield on almost all sprayed trees was heavy in 1942. Over the two year period the crop, on the average, was larger when the reduction in set was less in the "on" year.

It will be observed (Table III) that though the flowers formed in the "off" year (1942) per given branch length or area was only 13 to 51 per cent of that in the "on" year (1941), they were much more efficient in fruit setting. Evidently this was due not to a single but to several causes. When most of the bloom is destroyed by caustic sprays in the "on" year, flower buds usually are initiated but not as extensively as in an "off" year. And the fewer flowers the larger is apt to be the number that will set fruit. In addition, because of a favorable combination of climatic factors, 1942 was an unusually fruitful "off" year not only in this orchard but over a large territory in the Central States. Furthermore, the induction of flower buds, but especially of fruit setting, very likely was promoted by the condition of these trees (see footnote, Table III). Though bridge-grafted successfully, practically all of them had "stem injury". This partial stem "ringing" most likely fostered flowering and fruiting, but apparently was not strong enough a factor to initiate and maintain continuous annual flower and fruit production, as is evidenced by the performance of the control trees. This point will receive further attention in another paper (4).

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[4] Financial assistance for this experiment was provided by the Reilly Tar and Chemical Corporation, Indianapolis, Indiana.

SUMMARY

The apple crop in the "on" year of biennially bearing varieties may be eliminated partly or completely by means of caustic sprays applied thoroughly in the late cluster bud stage. For partial reduction of the fruit set a .5 per cent concentration of creosote oil (preferable), tar oil distillate or dinitro phenol (one-quarter dormant strength) may be used for experimental trial, though "fruit thinning" by this practice appears to be uncertain. For a complete kill of the bloom, a 2 per cent concentration of the above materials may be recommended. It is difficult to destroy by a single spray application all of the flowers on trees that have a considerable amount of delayed or late flower buds capable of setting fruit. Elimination of the crop in the "on" year does not always assure flower and fruit production in the "off" year, especially on trees of relatively low vigor.

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Thinning Wealthy Apples at Blossom Time with a Caustic Spray Compared to Hand Thinning After the June Drop

By A. Van Doren and M. B. Hoffman, *Cornell University, Ithaca, N. Y.*

IT IS characteristic of Wealthy to bear biennially. Heavy thinning of the fruit of this variety during the on-year is a necessary operation if apples of commercial size are produced. The thinning required together with the strong tendency toward alternate bearing makes Wealthy an expensive apple to grow.

It has been shown (1) that when Wealthy trees are in a moderate to good state of vigor, a dilute solution of the sodium salt of dinitrocresol (Elgetol) can be used as a spray to reduce the set at bloom time. This is a report of an attempt to compare blossom thinning by spraying, hand thinning during the summer, and a combination of those two treatments with respect to both the amount of labor required and the volume and grade of fruit produced.

Mature Wealthy trees 36 years of age were selected in the Pomology orchard at Ithaca, New York. The trees were vigorous, fairly well pruned and heavily budded. Since these trees were interplanted in a variety orchard containing several different varieties of apples in the block, good pollination supplemented the self-fruitful tendencies of the Wealthy. The center blossoms on many of the Wealthy spurs were open May 6, 1942. The trees reached full bloom on May 8, 1942, at which time 0.2 per cent Elgetol was applied. Eleven trees received the treatment and eleven trees were left untreated as checks.

All blossoming spurs on two representative unit branches of each tree were recorded at bloom time. The fruits on these branches were counted after the June drop. From these data the average number of fruits set per 100 blossoming spurs was calculated for each treatment. Expressed in this way, 20 to 25 fruits per 100 blossoming spurs is considered a commercial crop for Wealthy.

Six of the check trees were carefully hand thinned after the "June drop", spacing the fruits 7 to 8 inches. Six of the trees that had been sprayed with Elgetol were similarly thinned. Records were kept of the numbers of fruits thinned off of each tree as well as the time required in the hand thinning operation. Total yield per tree and number of fruits per bushel were recorded at harvest time.

The rate of growth or increase in diameter of the fruit was determined for the check trees and for those trees sprayed during the bloom. Twenty apples on each of five trees were tagged and circumference measurements, in centimeters, were made periodically of each fruit with a device similar to that described by Morris (2). From these data the average diameter in inches was calculated.

The data in Table I shows the extent to which the spray reduced the fruit set. There was an average of 59 fruits per 100 blossoming spurs on the check and 28 fruits per 100 blossoming spurs on the sprayed trees. The average yield was approximately the same for both

TABLE I—THE EFFECT OF ELGETOL APPLIED DURING BLOOM ON SET AND YIELD OF WEALTHY APPLES

Tree Location Number in Orchard	Average Number of Fruits Per 100 Blossoming Spurs	Diameter of Unit Branch Used for Blossom Count (Cm)	Number Fruits Per Bushel	Yield Per Tree (Bushel)
		Check—No Treatment		
T'3	77	3.34	186	13.9
T'6	55	1.15	193	33.7
T'7	59	2.92	187	27.3
T'8	68	3.46	183	23.6
T'9	39	3.11	177	27.0
Average..	59.0	2.8	185	25.1
		Sprayed With 0.2 Per Cent Elgetol		
S'3	35	3.29	183	23.1
S'4	31	3.16	145	27.4
S'5	22	2.59	143	18.2
S'6	28	3.26	175	29.9
S'7	24	3.28	148	29.2
Average.....	28.4	3.11	159	25.6

checks and treated trees, whereas the average size of the fruits from the trees sprayed with Elgetol was somewhat larger than that from the checks, being 159 apples per bushel for the sprayed trees and 185 for the checks.

A considerable reduction in the number of fruits necessary to be thinned off by hand was found where Elgetol had been applied at bloom time. Table II shows that in thinning fruits 7 to 8 inches, 3½ hours were required per tree to thin off an average of 6,017 fruits from the unsprayed trees while only 1.7 hours were required to thin off an average of 1,937 fruits from the sprayed trees. Trees receiving both the bloom spray and hand thinning treatments produced fruits about ¼ inch larger in size than those receiving only hand thinning. The counts being 122 and 143 fruits per bushel respectively. The average yield from all treatments was about the same.

TABLE II—THE EFFECT OF ELGETOL APPLIED DURING BLOOM PLUS HAND THINNING AFTER "JUNE DROP", COMPARED TO HAND THINNING ONLY

Tree Location Number in Orchard	Average Per Cent Set of Fruit Per Tree Per Treatment*	Number Apples Thinned Off by Hand Per Tree	Hours Required in Hand Thinning Each Tree	Number of Apples Per Bushel	Total Yield Per Tree (Bushels)
		Hand Thinned Only			
T'12		6,617	4.25	125	30.0
T'13		6,917	4.25	152	30.5
T'14		6,752	4.00	155	29.0
T'15		3,562	2.16	137	21.5
T'16		6,226	4.00	135	26.1
T'17		3,014	2.25	155	16.8
Average....	59.0*	6,017	3.49	143	25.6
		Sprayed With 0.2 Per Cent Elgetol Plus Hand Thinning			
S'12		2,080	1.75	130	29.7
S'13		2,320	2.70	120	29.7
S'14		1,219	1.08	103	15.2
S'15		1,750	1.50	118	19.9
S'16		2,272	1.66	137	25.0
S'17		1,978	1.50	128	22.6
Average. .	28.4*	1,937	1.7	122.5	23.7

*Average for five trees from each treatment.

The early elimination of potential fruits on the sprayed trees reduced competition between the remaining fruits so that the size of these individual fruits was greater than those of the check trees at the outset. This lead was increased throughout the remainder of the growing season finally resulting in apples of about ½ inch larger size (Table III). The 2.16 inch apples produced by the checks were unmarketable while the larger size of 2.61 inches which developed on the sprayed trees would be acceptable in most trade channels. As shown in Table II this size could have been increased further by supplementing the bloom spray with some hand thinning.

TABLE III—The Effect of Elgetol Applied During Bloom on the Rate of Increase in Size of Wealthy Apples During the Growing Season

Dates When Measurements Were Taken	Average Diameter of 100 Apples on Five Check Trees (Inches)	Average Diameter of 100 Apples on Five Trees Sprayed With 0.2 Per Cent Elgetol in Bloom (Inches)
June 11	0.96	1.02
June 18	1.10	1.18
June 25	1.24	1.35
July 2	1.42	1.58
July 9	1.57	1.76
July 15	1.65	1.88
July 29	1.85	2.12
August 6	1.93	2.21
August 12	1.98	2.29
August 20	2.04	2.38
September 4	2.11	2.49
September 13	2.16	2.61

The foliage suffered only slight to moderate injury on the sprayed trees and was scarcely detectable 10 days after application. There was noticeably more foliage and somewhat larger leaves during the growing season on the trees that had received the spray. The early removal of excessive numbers of fruits had apparently permitted a more adequate supply of foliage to develop.

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The Annual Bearing of Wealthy Apple Trees as Influenced by Thinning the Fruit at Blossom Time With a Caustic Spray

By M. B. Hoffman and J. D. VanGeluwe, *Cornell University, Ithaca, N. Y.*

THE summer of 1941 was the on-year for a block of Wealthy apple trees which had developed a distinct biennial bearing habit. As is usual in such cases, these trees were very heavily budded. During the blooming season, several spray treatments were applied to different groups of trees in an attempt to thin the fruit to that of a commercial crop. Dilute solutions of the sodium salt of dinitro-cresol (Elgetol) were used for the purpose. The degree of thinning accomplished with the various treatments together with tree yields and data on fruit size have been reported (1).

In the spring of 1942, it was observed that the trees receiving several of the blossom spray treatments the previous season had again formed fruit buds in appreciable amounts. None of the trees blossomed as heavily as typical biennial Wealthies do in the on-year. However, the blossoming spurs were very evenly distributed over the entire fruiting area of each tree.

None of these trees were given a bloom spray in 1942 because they did not carry the usual heavy bloom of an on-year tree and it was not possible to predict how well the fruit would set. It later developed that a 1942 bloom spray might have been profitably used since hand thinning was necessary to produce fruit of commercial size on the trees sprayed twice with the 0.2 per cent spray, and those receiving the single applications of 0.3 and 0.4 per cent spray during the 1941 bloom season. Most of the hand thinning was confined to breaking clusters, and about the same number of apples were removed from each tree as were left to develop.

Table I gives the performance records for those trees for the past 2 years.

The 1942 yield records would seem to indicate that those bloom treatments which caused the most foliage injury made the greatest contribution toward annual bearing. This point needs some explanation. Foliage injury as recorded in the table refers to the initial injury immediately following the application. The duplicate application of 0.2 per cent spray and the single application of 0.4 per cent spray did cause considerably more marginal burn on the leaf surface present at bloom time than did the single applications of weaker concentrations. This marginal burn was quite in proportion to the concentration and number of applications.

The stronger concentrations at full bloom, 0.3 and 0.4 per cent and duplicate application of 0.2 per cent reduced the fruit set more than did the weaker concentration 0.2 per cent at full bloom or any of the applications made prior to full bloom. This greater elimination of fruits permitted a more rapid development of foliage; so that, 3 weeks follow-

TABLE I—THE EFFECT OF ELGETOL APPLIED DURING THE BLOOM ON THE ANNUAL PRODUCTION OF WEALTHY APPLE TREES

Per Cent Concentration	1941		Foliage Injury	1942	
	Average Number Fruits Per Bushel*	Average Number Bushels Per Tree*		Average Number Fruits Per Bushel*	Average Number Bushels Per Tree*
No Hand Thinning					
Check......	182	15.4	———	108	2.6
Hand Thinned June 23					
Check.......	116	11.5	———	104	2.0
Sprayed April 30, Flowers 75 Per Cent Open					
0.1........	165	14.0	None	116	2.3
0.2..........	149	14.5	None	108	6.0
0.3..	171	11.0	None	100	5.2
Sprayed April 30 and May 1, Flowers 75 Per Cent Open and Full					
0.2....	119	13.5	Medium	122	18.7
Sprayed May 1, Full Bloom					
0.2..	124	15.0	Slight	110	8.7
0.3 . ..	100	13.0	Slight	96	13.3
0.4.. .	96	11.7	Medium	122	13.8

*Based on three average sized trees in each treatment.

ing full bloom the general appearance of the foliage on all treatments was in somewhat the reverse order to that which was recorded several days after the spray was applied. By the first of June the trees which had received the duplicate application of 0.2 per cent spray and those sprayed with 0.3 and 0.4 per cent spray concentrations at full bloom had developed the most vigorous foliage of any of the on-year Wealthy trees in the orchard. It required a careful inspection of these trees to observe any of the foliage injury caused by the bloom spray. Very slight foliage injury was still apparent in mid-summer where the treatments did not reduce fruit set sufficiently to permit a vigorous leaf growth.

The second consecutive crop reported for some of these Wealthy trees was due to the more luxuriant foliage which developed as a result of the reduction in fruit set caused by the bloom sprays. This is supported by the conclusions of Harley, *et al.* (2).

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Fruit Thinning Experiments with the Loquat

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IN a previous report (1), based on two seasons of work, evidence was presented which was considered to support the conclusion that fruit-cluster thinning applied prior to the period of natural fruit-drop in the loquat results in an increase in the size of the fruit left which is approximately proportional to the per cent of fruit-clusters removed. It was noted, however, and attention directed to the fact, for which no adequate explanation was then available, that the effects obtained in the thinning treatments the second season were much less marked than those which had occurred the first season. Data are now available from two additional seasons of work and are believed to provide the necessary basis for an understanding of this difference in response. This, together with the fact that it now seems highly improbable that the investigation can be continued for some time to come, is considered to warrant a report at this time.

EXPERIMENTAL MATERIALS AND PROCEDURES

Most of the experimental materials have already been described (1). For the purposes of this report, however, it is necessary to state that the trees of the Champagne and Thales varieties are all of the same age, planted in 1930, and the members of each pair approximately of the same size. On the other hand, one member of each pair of the Advance and Early Red varieties, trees 5 and 9 respectively, is three years younger and considerably smaller. For the limb treatments pairs

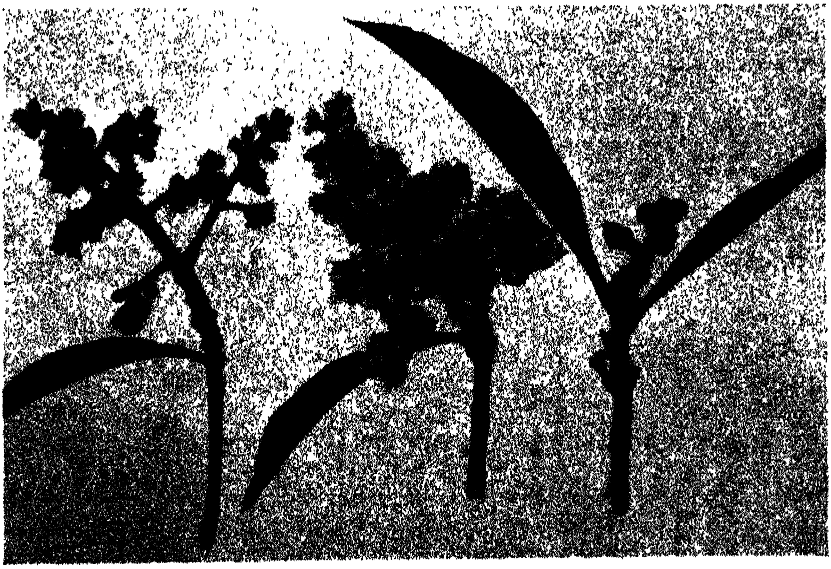

FIG. 1. Stages in the development of the loquat flower-cluster.

of limbs of approximately the same size and exposure were selected, one on the east side of the tree and the other opposite it on the west. In each case the balance of the tree served as control.

Because of the facts that the flower-buds are large and terminal and the fruits borne in relatively large clusters (Fig. 1), fruit-thinning may be accomplished in a variety of ways and over a relatively long period. Thus it may be done by a light pruning in late August or early September which removes merely terminal buds. This was the method employed in the 1940–41 tree treatments. At a slightly later stage (Fig. 1), it may be quickly and easily accomplished by breaking off part of the unexpanded flower-clusters. This method was used in the 1941–42 tree treatments. Still later, when the cluster is fully expanded and the flowers open (Fig. 1) it may be done by cutting off part of the flower-clusters. This method was employed in the 1939–40 tree treatments. Or it may be delayed until the fruit has set and the fruit-cluster is approaching the period of natural fruit-thinning, at which time part of the clusters are removed. This method was used in the 1938–39 tree treatments. And finally it may be accomplished in the fruit-cluster stage by the removal of part of the fruits from each cluster, obviously much the most tedious and expensive method. This method was used in some of the limb treatments. While adequate data are not available, the present evidence does not indicate greater effectiveness for any of the methods which involves the removal of flower-clusters. As will be seen later, however, there is slight evidence that fruit thinning may be somewhat more effective than fruit-cluster thinning.

In the 1938–39 treatments the crops were all harvested at the same time, May 19, when only part of the fruit on even the early varieties was ripe. In the subsequent treatments pickings were made at intervals of a week or 10 days throughout the fruit-ripening season. At each picking all clusters which showed ripe fruits were removed. In all cases each picking was sorted into three maturity grades and counts and weights obtained. For the 1940–41 tree treatments leaf counts and shoot-growth measurements were made for the Thales trees, May 20–21, toward the end of the fruit-harvesting season, and total soluble solids-acid ratio determinations were made for early, medium and late fruit-clusters on the Champagne trees.

While the number of trees involved is small, and the variability considerable, it is believed that the results obtained are indicative of the responses of this fruit tree to thinning.

DATA AND RESULTS

The essential data are summarized in Tables I and II and for part of the tree treatments are graphically portrayed in Fig. 2.

Tree Treatments:—From Table I it will be noted that in seven of the eight trials, involving four varieties and distributed over a period of 4 years, thinning resulted in increase in weight of fruit. The per cent of increase varied notably, however, ranging from 62 to 70 in the 1938–39 treatments, and from 14 to 52 in the 1939–40 treatments. In the 40–41 treatment a decrease of 7.3 per cent occurred, followed the next year by an increase of 19 per cent. In this connection it will

TABLE I—Fruit-Cluster Thinning in the Loquat; Tree Treatments

	1938-39			1939-40			1940-41			1941-42		
Variety and Tree Number	Treatment	Number Fruits Harvested	Average Weight Per Fruit (Grams)	Treatment	Number Fruits Harvested	Average Weight Per Fruit (Grams)	Treatment	Number Fruits Harvested	Average Weight Per Fruit (Grams)	Treatment	Number Fruits Harvested	Average Weight Per Fruit (Grams)
Advance 3	Control	7265	11.0									
Advance 5	Cluster-thinned March 2-10	2115	17.8									
Early Red 1				Cluster-thinned December-January. 46.5 per cent removed	9618	16.5						
Early Red 9				Control	6978	14.4						
Champagne 11	Control	11012	11.8	Cluster-thinned December-January. 50.1 per cent removed	7150	19.3	None	11828	16.8	None *	12617	15.9
Champagne 13	Cluster-thinned March 2-10	3477	19.8	Control	9343	15.6	None	4280	24.0	None	13335	13.2
Thales 17	Cluster-thinned March 2-10	1194	23.5	Cluster-thinned December-January. 75.8 per cent removed	3317	23.3	Cluster-thinned by pruning in September. 79.6 per cent removed	1993	28.7	Cluster-thinned in September. 62.7 per cent removed	5557	23.8
Thales 19	Control	6097	13.8	Control	9691	15.3	Control	894	30.8	Control	9024	19.9

TABLE II—FRUIT-CLUSTER AND FRUIT THINNING IN THE LOQUAT; LIMB TREATMENTS

Variety and Tree Number	1940–41 Treatment	Per Cent Removed	No. Fruits Harvested	Average Weight Per Fruit (Grams)	1941–42 Treatment	Per Cent Removed	No. Fruits Harvested	Average Weight Per Fruit (Grams)
Advance 5	Control..	00.0	5226	9.9				
	Early cluster thinned.	58.9	2350	11.2				
	Late cluster thinned	50.6	2016	10.9				
Early Red 9	Control........	00.0	3458	18.6				
	Early cluster thinned......	55.1	601	20.2				
	Late cluster thinned......	51.5	737	20.6				
Premier 7	Control........	00.0	4273	17.5				
	Fruit thinned .	71.7	1568	21.8				
	Cluster thinned	62.4	1301	19.3				
Unknown 21	Control	00.0	3926	19.9				
	Fruit thinned. .	71.3	243	24.8				
	Cluster thinned.	68.7	215	21.5				
Early Red 1					Control..	00.0	14487	11.5
					Fruit thinned .	77.4	1737	20.5
					Cluster thinned.	72.6	1597	18.2
Early Red 9					Control	00.0	7620	12.0
					Fruit thinned	75.4	707	15.0
					Cluster thinned	72.0	1185	12.8

be noted that a flower-cluster thinning which removed 75.8 per cent of the clusters from Thales tree 17 in 1939–40 resulted in an increase in fruit weight over the control tree of 52 per cent, whereas the removal of 79.6 per cent of the clusters from the same tree the following year resulted in an average fruit weight 7.3 per cent less than that on the control tree.

The explanation for this apparently inconsistent response must, of course, be sought in the bearing behavior of the control tree. The reason appears to be the fact, which the table discloses, that in 1940 this tree produced 9691 small fruits, whereas the following year it produced only 894 fruits which, however, averaged twice as heavy. Obviously the leaf area per fruit in 1940–41, which was 155.6 square centimeters, was very much larger than the previous season. Indeed it was two and a half times that of the thinned tree, 63.4 square centimeters per fruit, yet the fruit was only slightly larger. It seems certain, therefore, that some factor other than the ratio of leaf area per fruit was operative in this tree, the effect of which was to greatly reduce the number of flower clusters in the 1940–41 crop and prevent the fruit from attaining the size that would be expected to result from so large a leaf area per fruit. In this connection it may also be mentioned that the average length of shoot growth on this unthinned tree, as determined May 21, 1941, was only 9 centimeters as compared to 12 centimeters for thinned Thales tree 17, which carried a crop of more than twice as many fruits.

This factor is believed to be the excessive number of fruits produced in the 1939–40 crop, actually the largest number in any crop produced to date. The relationships involved are graphically portrayed in Fig. 2, which reveals the fact that whereas both trees have alternated consistently during the period under study the amplitude of alternation exhibited by the control tree has been much greater than that shown by the thinned tree. Indeed the behavior of the latter is considered to afford strong evidence that thinning may provide a practicable means for controlling the alternate bearing tendency in this fruit.

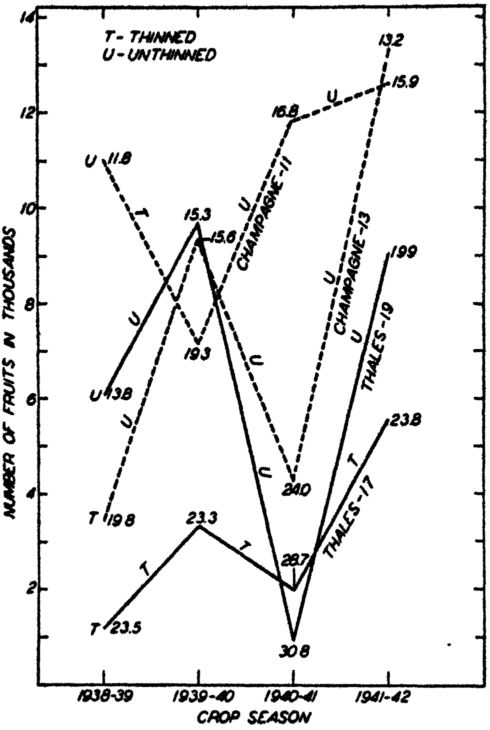

FIG. 2. Bearing behavior, crops, and average weights per fruit of four paired loquat trees for four consecutive crop seasons.

Additional evidence bearing on the relationship which seems to exist between number of fruits and weight of crop in the preceding crop and the number and size of the fruits in the succeeding crop is afforded by the behavior of the Champagne trees, both of which were thinned once during the first half of the period under study and not thereafter. It will be noted that, whereas in the 1939–40 crop the thinned tree produced fruits which averaged 23 per cent heavier than the fruits on the control tree, the following year, when neither was thinned, the situation was reversed and the fruit from the latter exhibited a percentage increase of 43, nearly twice that of the previous season, and the following year, when no thinning was practiced, the situation was again reversed with a percentage increase of 20 in favor of the tree thinned in 1939–40 but not thereafter. The probable reason for the reversal and difference in the 1940–41 crop, as depicted in Fig. 2, seems to relate to the wide amplitude of alternation of the two trees in *opposite* phase, a condition which seems to have been brought about by the initial thinning treatments. And the probable reason for the reversal which occurred in the 1941–42 crop would seem to be the fact that the thinning in 1939–40, in which 50.1 per cent of the clusters was removed, did not reduce the number of fruits sufficiently to bring about reduction in total weight of crop over that of the previous season. As a consequence the amplitude of alternation established in this tree was less pronounced than that produced in the other member of this pair. In this connection it will be noted that Champagne variety appears to be characterized by heavier bearing than is the case with Thales.

It is believed that the behavior of these trees, together with the data on the effects of cluster thinning, support the conclusion (a) that the loquat exhibits a marked tendency to alternate bearing; (b) that there are two factors primarily concerned with the size of fruit in any given crop, namely the size and weight of the preceding crop and the leaf area per fruit in the current crop; and (c) that thinning is much less likely to be effective on trees in the off-crop phase than on trees in the on-crop phase.

The fact that two of the three thinned trees in the 1939–40 crop season were in the off-crop phase is evidently the reason for the reduced effectiveness of thinning reported for that season (1).

Limb Treatments:—Reference to Table II reveals the fact that in all six limb treatments, involving four varieties and spread over two seasons, thinning was effective in increasing fruit weight. With one exception however, Early Red tree 1 in the 1941–42 season, the increases were moderate or small. Moreover, it is of interest to note that the larger increases in all cases occurred on trees in the on-crop phase. And with one possible exception, the data indicate greater effectiveness associated with heavier thinning.

The limited data available seem not to show any benefit from early thinning, done December 10 to 12, over late thinning, done January 30, but there is at least the slight indication that fruit thinning was more effective than fruit-cluster thinning.

Summary and Conclusions

Four years of experiments with pairs of loquat trees of four varieties and 2 years of paired limb trials in five trees, involving two additional varieties, are considered to support the following conclusions:

1. The loquat tree exhibits a pronounced tendency to alternate bearing, in which large crops are associated with small fruit size and vice versa.
2. Size of fruit in any given crop is determined mainly by the number and weight of fruits in the preceding crop and the leaf area per fruit in the current crop.
3. Flower cluster, fruit cluster or fruit thinning provide practicable means for minimizing and controlling the alternate bearing tendency.
4. The increase in fruit size which results from thinning is roughly proportional to the per cent of flowers or fruits removed.
5. Thinning is less effective in trees which are in the off-crop phase.

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Pre-Harvest Sprays in Ohio in 1942

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THE pre-harvest spray tests at the Ohio Experiment Station in 1942 were largely restricted to three principal varieties — McIntosh, Delicious and Stayman Winesap — with limited attention to Red Rome Beauty. Only one material, a commercial brand of naphthaleneacetic acid was applied at the concentration recommended by the manufacturer. Sixteen trees of each of the three principal varieties and eight of Red Rome Beauty were used. The trees were mature, ranging in age from 18 to 27 years. A medium sized orchard sprayer was employed to apply the material to the trees which were thoroughly drenched.

The trees of McIntosh, Delicious and Stayman Winesap were divided into four groups of four trees each; four trees were left unsprayed, the other three groups of trees were sprayed at three different times. The individual trees in each of the four plots were separated some distances from other trees in the same plot. The McIntosh and Delicious were picked at two different times. The Stayman Winesap were all harvested the same day. On each of the trees in the sprayed plots a series of branches, usually four in number, were covered with paper bags to exclude the spray solution just previous to the spraying of the remainder of the trees. A count of the apples on each branch was made after the bag had been removed. An equal number of comparable sprayed branches were likewise tagged and the fruits counted as soon as the trees were dry from the spraying. The number of fruits on these branches were also counted at intervals from the date of spraying until the fruits were harvested. Counts were also made of the number of apples under the tree at the time the spraying was done, and also of the number of drops under each tree at intervals during the period and on the day the tree was picked.

Finally, the total number of apples on the whole tree were counted at the time the apples were harvested. The data secured from the observations made on the sprayed and unsprayed individual limbs are presented in Table II. Data from the counts made of the behavior of the sprayed and unsprayed whole trees are presented in Table I. In considering the data for the sprayed whole trees corrections have been made, taking into account the number of fruits on the unsprayed branches of these trees.

WEATHER OBSERVATIONS

The material was always applied either shortly before or after noon. The McIntosh trees were sprayed between 1:30 and 2:00 p.m. Temperatures at the time the solution was applied, as well as the range of temperatures from the date of spraying until the fruit was harvested, are shown in Table III. The temperatures at the time of spraying the McIntosh were as follows: August 26, 78 degrees; August 28, 76 degrees; and September 3, 76 degrees. During the whole of the period from the date of the first spraying of McIntosh until the second date of harvesting the temperatures were about normal for the period ranging from about 55 degrees at night to as high as 85 degrees during the day. Humidity was fairly high most of the time.

Temperatures at the time of the three applications on the Delicious plots were respectively, 52, 56, and 62 degrees. The applications were made in each case at 2:00 p.m. During the time the spraying was under way with Delicious the daily temperatures were rather constant, but somewhat below normal for that period. Beginning October 1 and continuing until the date of the second picking of Delicious on October 9, temperatures were about normal.

Temperatures at the time the Stayman Winesap were sprayed were October 5, 64 degrees; October 9, 70 degrees; and October 13, 62 degrees. These temperatures are about what could be expected during this period, and seasonal weather continued until the Stayman Winesap were harvested.

SEVERE DROP

A very severe drop occurred before the Stayman Winesap were harvested. This drop was general throughout the State. Practically all varieties not harvested before October 10 suffered, but in the vicinity of Wooster, Stayman Winesap suffered as badly as any variety. The first observation made in the Station orchard of this very heavy drop was the afternoon of October 10. By noon of October 11 from 25 to

TABLE I—INFLUENCE OF PRE-HARVEST SPRAY ON PREVENTING DROPS (1942)—DATA FROM WHOLE TREES

Date Sprayed	Date Harvested	Percentage of Drops Between Spraying and Picking Dates	
		First Picking Date	Second Picking Date
	McIntosh		
Aug 26	Sep 11	16.9	—
Aug 26	Sep 22	14.7	42.5
Aug 28	Sep 11	13.8	—
Aug 28	Sep 22	7.0	26.2
Sep 3	Sep 11	6.0	—
Sep 3	Sep 22	4.7	18.5
Unsprayed trees	Sep 11	13.0	—
Unsprayed limbs*	—	17.6	—
Unsprayed trees	Sep 22	40.8	74.7
Unsprayed limbs*	—	—	34.6
	Delicious		
Sep 21	Oct 2	8.5	—
Sep 21	Oct 9	8.5	12.2
Sep 25	Oct 2	25.5	—
Sep 25	Oct 9	28.4	39.8
Sep 28	Oct 2	9.3	—
Sep 28	Oct 9	11.4	18.5
Unsprayed trees	Oct 2	44.0	—
Unsprayed limbs*	—	10.0	—
Unsprayed trees	Oct 9	7.2	24.2
Unsprayed limbs*	—	—	25.1
	Stayman Winesap		
Oct 5	Oct 18	23.2	—
Oct 9	Oct 18	22.1	—
Oct 13	Oct 18	41.8	—
Unsprayed trees	Oct 18	82.7	—
Unsprayed limbs*	—	54.2	—

*These limbs were on sprayed trees.

35 per cent of the crop on many trees had dropped. The velocity of the wind was not abnormal during this period. It will be noted that the dates of spraying for the Stayman Winesap were October 5, 9 and 13. The first application was made 5 days before the beginning of the drop and the second application just 1 day before, while the third application was not made until 4 days after the drop started.

McIntosh:—A summary of the results secured in spraying McIntosh is shown in Table I. The percentage of drops on the four unsprayed

TABLE II—EFFECT OF PRE-HARVEST SPRAYS UPON FRUIT DROPPING (1942)

Treatment	Number Trees	Number Pairs of Branches	Per Cent Fruits Dropping			F* Value	5 Per Cent Point
			Un-sprayed Branches (Ave)	Sprayed Branches (Ave)	Un-sprayed Minus Sprayed		
			McIntosh				
Sprayed Aug 26…… Picked Sep 11……..	2	8	28.0	15.6	12.4	2.34	4.75
Sprayed Aug 26…… Drop by Sep 11……	2	7	11.8	17.3	−5.5	1.41	4.96
Sprayed Aug 26…… Picked Sep 22……..	2	7	46.9	41.8	5.1	0.23	4.96
Sprayed Aug 28…… Picked Sep 11……..	2	8	20.6	15.1	5.5	0.69	4.75
Sprayed Aug 28…… Drop by Sep 11……	2	7	6.0	9.8	−3.8	0.86	4.96
Sprayed Aug 28…… Picked Sep 22……..	2	7	11.4	23.1	−11.7	4.12	4.96
Sprayed Sep 3 …… Picked Sep 11……..	2	8	4.1	3.8	0.3	0.01	4.75
Sprayed Sep 3……. Drop by Sep 11…….	2	8	15.3	3.5	11.8	4.47	4.75
Sprayed Sep 3……. Picked Sep 22……..	2	8	44.2	9.8	34.4	18.68†	4.75
All trees…….…… Drop by Sep 11……	12	46	14.5	10.7	3.8	2.60	3.98
All trees………… Picked Sep 11……..	6	24	17.6	11.5	6.1	2.73	4.11
All trees………… Picked Sep 22……	6	22	34.6	24.2	10.4	4.70	4.15
			Delicious				
All trees Oct 2……..	12	47	11.3	13.0	−1.7	1.16	3.98
Trees picked Oct 2….	6	23	10.0	11.8	−1.8	0.58	4.13
Trees picked Oct 9….	6	24	25.1	20.7	4.4	0.76	4.11
			Stayman Winesap				
Sprayed Oct 5…….. Picked Oct 18……..	4	16	67.8	23.4	44.4	69.83†	4.26
Sprayed Oct 9…….. Picked Oct 18……..	4	16	63.1	28.8	34.3	24.93†	4.26
Sprayed Oct 13……. Picked Oct 18……..	4	15	31.9	37.8	−5.9	1.71	4.30
			Red Rome Beauty				
All trees………….	6	16	36.3	40.5	−4.2	0.47	4.35

*Snedecor (2).
†Significant to 1 per cent point also.

trees at the time of the first picking on September 11 was somewhat in excess of that on sprayed trees but not great enough to warrant the conclusion that the differences were significant. Of the trees harvested on September 22 there was an appreciable difference in favor of the sprayed trees. However, it should be stated here that September 22 was late for a satisfactory picking date.

The data for the sprayed and unsprayed branches are presented in Table II. Fruit dropping from the branches sprayed on the three dates was analyzed separately in relation to the first picking date, September 11 and the second September 22. It is to be noted that there was no significant difference in the drop from sprayed and unsprayed limbs on September 11 regardless of the time of spraying. On the other hand, the difference between the limbs was significant on September 22. As indicated by the data in Table II this was largely due to the favorable effect of the last spray applied September 3. Unfortunately, however, the fruits left until this late picking date were over-mature since the proper picking date from the point of view of softness and maturity was September 11 to 15.

TABLE III—TEMPERATURES DURING THE PERIOD COVERED BY PRE-HARVEST SPRAY EXPERIMENTS (1942)

Variety	Temperatures at Time of Application			Range of Temperatures From Date of Spraying to Picking	
	First Spray	Second Spray	Third Spray	First Picking	Second Picking
McIntosh	78	76	76	42–85	42–86
Delicious	52	56	62	29–80	29–80
Stayman Winesap . .	64	70	62	46–82	——

It is to be noted that the drop from the two unsprayed McIntosh trees which were picked September 22 was much greater on September 11 than that of the two unsprayed trees which were picked on this date. It is possible that the fruits on the trees picked September 22 were more mature at a given date since they carried a somewhat smaller crop than the unsprayed trees picked earlier. In Table I the data for the unsprayed limbs were taken from the sprayed trees. These results indicate the value of supplementing data taken from spraying whole trees with that obtained from unsprayed limbs on the same trees.

Delicious:—It will be noted from Table I that in the case of the trees sprayed September 21 and 28 there seemed to be notably fewer drops than on the unsprayed trees. However, the trees sprayed September 25 dropped as much, or more than did the unsprayed trees. Considering the whole number of sprayed trees together and comparing them with the unsprayed trees there seems little to indicate that the spray material retarded dropping on the variety as a whole. It will be noted that this conclusion is in conformity with an analysis of the data from the individual limbs presented in Table II. As shown by the data there was clearly no significant effect of the sprays upon the drop of fruits either at the first picking date or at the second.

Stayman Winesap:—In the case of Stayman Winesap, Table I, it should be noted that the trees which were sprayed on October 5 were sprayed 5 days before the abnormal drop began. Plot 2 was sprayed about 11:30 a.m. on October 9 and by the evening of October 10 there was evidence that the heavy drop was beginning. The data indicate that this plot was sprayed early enough for the material to be effective in reducing the drop of this plot. Plot 3 was not sprayed until 3 days after the drop had started, and it might be expected that the results from this plot would be confused. Two of the three sprayed plots of Stayman Winesap did show appreciably fewer drops than the unsprayed plots. Work in 1940 and 1941 at this Station previously reported (1) showed favorable response with Stayman Winesap.

The data in Table II show an outstanding effect of the sprays applied October 5 and 9 in reducing the drop occurring up to the time of harvest, October 18. On the other hand, the spray applied October 13 in the middle of the severe drop was ineffective in reducing the drop. Furthermore comparison of F values indicate that the spray applied 5 days in advance of the drop was more effective than that applied one day in advance.

Red Rome Beauty:—The drop of fruit on this variety was not affected by the pre-harvest spray. The difference between the sprayed and unsprayed branches (Table II) was not significant.

SUMMARY

McIntosh, Delicious, Stayman Winesap and Red Rome Beauty were sprayed with commercial naphthalene acetic acid. Favorable results were secured only on Stayman Winesap. The drop of fruits from the last spray applied to McIntosh significantly affected the drop of fruits up to the last picking date September 22nd but the fruits were decidedly over-mature.

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The Efficiency of Harvest Sprays After a Freeze

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FOR two years branches of various varieties of apples have been thoroughly sprayed with commercially recommended "harvest sprays", using a hand sprayer. The object was to determine the effect upon dropping and to observe the mechanical nature of "abscission". As applied, the sprays were ineffective in delaying dropping in the cases of Wealthy, McIntosh, Grimes Golden, Early McIntosh, and Macoun, but were effective with Diana, Snow (Fameuse), and Spy.

An unseasonable cold spell in late September, 1942, furnished an opportunity to secure data on the effect of a harvest spray applied after a freezing spell and also when the temperature is low. "Appel-set" was used at the rate of ¼ pound per 100 gallons of water.

September 24 to 27 inclusive, official maximum temperatures of 43, 47, 40, and 44 degrees F were recorded at Madison; the following nights the minimum temperatures were 30, 33, 32, and 30 degrees. Night temperatures in the orchard were 8 to 10 degrees lower than the official figures. On October 3 and 4 such varieties as Snow, Jonathan, and Golden Delicious dropped so completely in some orchards it did not pay to harvest the few apples remaining on the trees.

A commercial orchard of Snow at Gays Mills, Wisconsin, which was sprayed September 29, had no appreciable drop when the apples were picked October 10 to 12. Pilfering interfered with the earlier experimental trials on Snow, but an application on September 24, when the maximum temperature was 43 degrees F, held 96 per cent of the fruits as late as October 7 and 80 per cent until October 12, when the percentage remaining on the unsprayed branches was only 3.1.

Fruits on different trees of Spy began to loosen from October 5 to 10. On branches sprayed October 5 the percentages of fruit remaining October 14, 23, and November 10 were 77.8, 60.8, and 22.3 respectively compared to 28.9, 7.6, and 6.1 on unsprayed branches for the same dates. When the spraying was done October 12 on branches with apples that were becoming rather loose, the percentages remaining on the above dates were 93.6, 62.7, and 33.4 while the unsprayed branches held but 55.3, 21.4, and 15.9 per cent of their fruits. Most of the sprayed fruits held on for a sufficiently long time to permit harvesting before they dropped.

A number of reports have been received from commercial growers (who used other brands of harvest sprays) that spraying after the September cold spell was highly successful.

This season's results clearly indicate the practicability of spraying after a "freeze", and also that spraying was efficient this year when applied during a period of low temperature.

Comparative Results with Sprays and Dusts in Controlling the Preharvest Drop of Apples[1]

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IN controlling, or lessening, the preharvest drop of apples, preliminary comparative results with liquid and dust carriers of the active chemicals have been somewhat meager and variable. Usually, equivalent amounts of growth substances have been used per tree application in both dusts and sprays. In 1941, in New York, dusts were as effective as sprays in controlling preharvest drop with Williams, McIntosh, and Baldwin (1). In Massachusetts, on the other hand, dusts were comparatively ineffective (2). In this case, McIntosh was the only variety used.

In 1942, spray and dust applications were compared in Experiment Station orchards at Amherst. Three varieties were used: Duchess, Wealthy, and McIntosh. Applications on mature McIntosh consisted of about 30 gallons of spray and 3 pounds of dust and, on Wealthy and Duchess, similar liberal applications according to tree size. Thorough coverage was obtained in every case. The dusts usually were prepared so that 1 pound of dust was equivalent to 10 gallons of a standard (.001 per cent) liquid spray, in amount of active ingredients. Thus, theoretically, applications of 3 pounds of dust and 30 gallons of spray supplied equivalent amounts of the chemical or chemicals active in drop-control. This relationship was maintained as nearly as possible in all of the tests. Four different dusts and three commercial "hormone" spray materials were used. These will be referred to by number. In some tests, the pure naphthalene acetic acid was used.

DUCHESS

The first spray and dust applications were made on Duchess. Table I gives the subsequent drop and yield data.

TABLE I—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF DUCHESS (APPLICATIONS — AUGUST 5)*

Treatment	Per Cent Drop to Aug 7	Cumulative Per Cent Drop After August 7					Average Crop Per Tree (Bu)
		Aug 8	Aug 10	Aug 11	Aug 12	Aug 14	
Check	7.3	2.9	13.3	20.0	33.2	54.6	6.8
Dust (No. 3)†	4.6	2.8	10.8	16.2	23.6	35.7	7.7
Dust (No. 4)	6.5	2.9	9.2	13.5	19.1	28.6	6.2
Spray (No. 3) (.001 per cent)	9.7	0.9	2.9	4.3	5.6	9.3	12.1
Spray (No. 1) (.001 per cent)	4.3	0.8	2.4	3.8	4.2	6.5	7.4

*Two trees per treatment. Maximum temperature August 5, 75 degrees F.
†Numbers refer to commercial products.

On the basis of the drop to August 7, the applications were made at about the right time. The cumulative per cent drop from August

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[1] Contribution No. 463 from the Massachusetts Agricultural Experiment Station.

7 to 14 gives a good picture of the comparative effectiveness of the treatments. The two sprays were about equally effective and were significantly more so than either of the two dusts. The dusts were somewhat beneficial in lessening preharvest drop but it is doubtful that the results really justified the applications. In 1940, sprays were very effective in controlling drop with this variety (3).

WEALTHY

Tables II and III give the results of drop control tests with Wealthy.

TABLE II—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF WEALTHY (APPLICATIONS — AUGUST 20 AND 21)*

Treatment	Cumulative Per Cent Drop From August 22			Average Crop Per Tree (Bu)
	Sep 5	Sep 8	Sep 10	
Check	21.9	36.4	51.8	21.8
Dust (No. 2)	22.8	41.4	58.9	28.0
Spray (No. 1) (.001 per cent)	20.8	36.9	52.0	24.5
Spray (No. 2) (.001 per cent)	12.1	29.8	47.0	34.4
N. acetic acid (.002 per cent)	7.7	21.4	39.5	19.4
N. acetic acid (.004 per cent)	3.8	7.2	15.6	31.5

*Two trees per treatment. Maximum temperature August 20, 86 degrees F and August 21, 90 degrees F.

In this table, the comparative drop percentages to September 5 are probably the more useful, since this was about normal harvest time and since the greatly increased dropping of treated trees after this date indicated that the effect of the treatment was wearing off. There was no lessening of preharvest drop due to the dust treatment or to spray No. 1. Spray No. 2 was partially effective.

The outstanding result of these tests was the correlation of drop control with spray concentration. Using the pure acid (dissolved in small amounts of alcohol prior to putting in spray tank) a 20 parts per million spray was more effective than either commercial spray at the usual recommended strength (10 parts per million). Further, the 40 parts per million spray was significantly more effective than the 20 parts per million application. These differences were striking and easily discernable in the orchard to impartial observers. The fruit on the trees treated with the stronger sprays not only hung on better and longer, but was much more highly colored. On September 10 when about one-half of the apples had dropped from most of the trees even where 10 parts per million sprays were used, less than one-sixth of the original crop had dropped from trees treated with the 40 parts per million spray. Previous results with McIntosh have indicated that higher concentrations may be required for effective control of drop in Massachusetts (2, 3).

Table III shows the effectiveness of some dust applications on another Wealthy block. As in the above test, the number of trees per treatment is small.

None of the treatments was particularly effective, and two applications were no more effective than a single one in this test. On the basis of experience with sprays, it is possible that a more highly concentrated dust would have given better results.

TABLE III—EFFECT OF DUST APPLICATIONS ON PREHARVEST DROP OF WEALTHY (FIRST APPLICATIONS — AUGUST 21; SECOND — AUGUST 29)*

Treatment	Per Cent Drop to Aug 21	Cumulative Per Cent Drop After Aug 21			Average Crop Per Tree (Bu)
		Sep 5	Sep 8	Sep 10	
Check	9.3	29.9	48.6	63.7	5.6
Dust (No. 2) one light application	11.5	26.6	50.8	67.9	6.4
Dust (No. 2) one heavy application	4.8	18.2	34.5	51.1	18.4
Dust (No. 2) two heavy applications	6.4	17.7	33.6	52.9	19.4

*Two trees per treatment. Maximum temperature August 21, 90 degrees F and August 29, 76 degrees F.

MCINTOSH

The most comprehensive tests were made with McIntosh. Table IV gives drop and related data for the check and nine treatments in a mature and uniformly bearing orchard.

TABLE IV—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF MCINTOSH (FIRST APPLICATIONS — SEPTEMBER 8; SECOND — SEPTEMBER 12)*

Treatment	Number of Applications	Per Cent Drop to Sep 11	Cumulative Per Cent Drop After September 11			Average Crop Per Tree (Bu)
			Sep 16	Sep 19	Sep 21	
Check	–	4.4	13.6	25.7	36.6	23.7
Dust (No 1)	1	5.9	12.7	26.6	43.9	23.5
Dust (No. 2)	1	5.5	8.2	18.3	32.3	24.3
Spray (No. 2) (.001 per cent)	1	8.4	5.8	16.0	31.3	28.4
Dust (No. 3)	2	4.8	11.4	19.1	30.1	22.0
Dust (No. 2)	2	6.9	7.8	13.9	26.2	27.3
Spray (No 1) (.001 per cent)	1	3.9	3.6	9.9	22.6	28.7
Dust (No. 1)	2	3.3	3.6	8.3	20.1	23.8
Spray (No. 1) (.002 per cent)	1	5.2	2.7	7.4	16.3	25.6
Spray (No. 1) (.001 per cent)	2	10.2	2.9	4.8	7.7	23.8

*Seven trees per treatment. Maximum temperature September 8, 72 degrees F and September 12, 67 degrees F.

The treatments are listed in ascending order of their effectiveness in controlling preharvest drop. Probably the cumulative per cent drop to September 19 gives the best comparative picture of results. Picking maturity was just about right at this time. Single applications of dust were rather unsatisfactory. A possible reason why spray No. 2 was not more effective is that this application (the last one made on September 8) failed to dry before the onset of a steady rain. A single application of spray No. 1 was considerably more effective than the single dust applications and two applications of dust No. 3. It was also somewhat more effective than two applications of dust No. 2. However with dust No. 1, very good control of drop was secured with two applications 4 days apart. The best treatment, spray No. 1 applied twice, was somewhat more effective than this same spray applied once at double concentration.

Summarizing, the last five treatments listed in Table IV were, in general, more effective in lessening preharvest drop of McIntosh than the four other treatments. On the basis of these results, dust applications show more promise with McIntosh than with Duchess or Wealthy.

Table V gives further evidence that, under the right conditions, dusting may be little inferior to spraying in controlling preharvest McIntosh drop.

TABLE V—EFFECT OF SPRAY AND DUST APPLICATIONS ON PREHARVEST DROP OF MCINTOSH (APPLICATIONS — SEPTEMBER 3)*

Treatment	Per Cent Drop Sep 5 to 15	Average Crop Per Tree (Bu)
Check	24.6	32.2
Dust (No. 4)	10.5	30.5
Spray (No. 3) (.001 per cent)	7.9	34.0

*Four trees per treatment. Maximum temperature September 3, 87 degrees F.

These applications were made in the morning of a quiet, hot and humid day. Conditions were especially ideal for dusting. The data show that in this test dusting was quite effective in lessening drop.

DISCUSSION

The comparative effectiveness of dust and spray applications in controlling the preharvest drop of Duchess, Wealthy, and McIntosh is reported. Approximately equivalent amounts of active ingredients were applied per tree whether dusted or sprayed. With Duchess and Wealthy, dusting was not so effective as spraying; while with McIntosh, though results were variable, dust applications gave encouraging control. Two applications, 4 days apart, gave better results than a single application. Likewise, the value of a second spray application on McIntosh was demonstrated.

Using Wealthy as a test variety, control of drop was correlated with spray concentration even to a 40 parts per million level. Also, with McIntosh a 20 parts per million spray was somewhat more effective than the standard 10 parts per million spray. These and previous results seem to indicate that under some conditions, more highly concentrated sprays will be more successful in controlling preharvest apple drop than the so-called "standard" 10 parts per million applications.

It would seem desirable, also, to experiment with dusts containing higher percentages of active ingredients. Even though comparative costs must be considered, the primary requisite in drop control spraying or dusting is the certainty and the degree of control.

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Further Tests on the Methods of Applying Naphthalene Acetic Acid for Control of the Pre-Harvest Drop of McIntosh Apples

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THE use of hormone sprays for delaying the pre-harvest drop of apples comes at one of the busiest times of the year for the grower. If a large planting of McIntosh is involved and the spray is used so as to furnish the maximum protection from drop throughout the harvest period, some spraying will probably have to be done after harvesting gets under way. With the increasing cost and scarcity of experienced help on many fruit farms, the expense and effort required for proper spraying becomes a more important item than the cost of the materials. For this reason growers have often expressed their interest in the development of a hormone dust.

Some preliminary work comparing the effectiveness of a naphthaleneacetic acid dust with that of the liquid spray has been reported (3). These tests were repeated in 1942. Two experimental dusts[1] designated here as A-1 and A-2 were used. The A-1 was similar to the dust used in the 1941 tests. Both were talc dusts containing exactly 0.1 per cent naphthalene acetic acid but varied somewhat in composition with respect to other ingredients. With this concentration of the active material, 1 pound of dust is approximately equivalent to 10 gallons of 0.001 per cent spray since both contain about 0.4 gram of naphthalene acetic acid.

It has been customary in this work to use about 1 gallon of liquid spray per bushel of fruit since thoroughness of the application has proven desirable. Accordingly, the dust for each treatment was accurately weighed out and 1 pound was allowed for each 10 bushels of fruit (estimated on the trees). In this way it seems that approximately the same amounts of naphthalene acetic acid were applied per bushel of fruit by both methods.

The first test was conducted in a vigorous 17-year-old McIntosh orchard in the lower Hudson Valley area. This was a very uniform block of trees, both in respect to size of crop and nitrogen level; the latter being judged by color of foliage and fruit as well as tree growth and fruit size. All treatments were made on August 31 when it was observed that fruits of good commercial quality had started to drop from most of the trees. The dusts were applied between 7:00 and 8:00 a.m. The leaves were wet with dew and the temperature at 8 a.m. was 58 degrees F. The liquid applications were made between 9:00 and 11:00 a.m. The temperature had risen to 73 degrees F at 11 a.m. and reached a maximum of 85 degrees at 2:30 p.m. On September 5, the treatments on two groups of the trees were duplicated. Again the dust was applied before 8 a.m. to take advantage of dew. The temperature was 56 degrees F at the time of dusting but had risen to 72 degrees F by 11:00 a.m. when the duplicate liquid spray was applied. All record trees were harvested on September 11 and 12. Table I gives the results of this test.

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[1] The American Cyanamid and Chemical Corporation, through its representative, Dr. J. L. Horsfall, supplied all dusts and chemicals reported on in this paper.

TABLE I—Effect of Naphthalene Acetic Acid Spray and Dust on the Dropping of McIntosh (First Application August 31; Second Application September 5; Fruit Harvested September 11 and 12)

Treatment	Number Applications	Cumulative Per Cent Drop—Original Crop*										
		Days After Spraying										
		2	3	4	5	6	7	8	9	10	11	12
Check	0	1.5	4.0	6.2	8.1	9.9	12.4	17.4	21.9	25.4	29.9	36.2
.001 per cent liquid spray	1	0.4	0.8	1.2	1.6	2.0	2.7	4.8	7.8	9.9	12.6	—
A-1 dust	1	0.8	1.6	2.1	2.6	3.1	3.9	5.8	8.5	9.8	12.5	—
A-2 dust	1	0.7	1.1	1.5	1.7	2.0	2.9	5.0	7.8	10.1	12.7	—
.0005 per cent liquid spray	2	0.5	1.0	1.4	1.8	2.0	2.3	3.3	4.3	5.1	5.3	6.0
A-2 dust	2	0.4	0.7	1.0	1.3	1.6	1.8	2.3	3.2	3.7	4.0	4.7

Temperatures	Aug 31	Sept 1	Sept 2	Sept 3	Sept 4	Sept 5	Sept 6	Sept 7	Sept 8	Sept 9	Sept 10	Sept 11	Sept 12
Maximum	85	84	85	86	76	78	75	74	74	73	80	77	71
Minimum	60	63	62	65	58	51	49	49	57	59	57	59	59

*Average of eight trees per treatment, 23.5 bushels total yield per tree.

Warm weather prevailed throughout the pre-harvest period as shown by the maximum and minimum temperatures recorded daily at the orchard. The behavior of the checks shows that an uninterrupted drop was starting at the time the materials were applied on August 31. Within 12 days, 36 per cent of the crop had dropped from the untreated trees. When single applications are considered, the two dusts were about equally effective in delaying drop and both gave as good results as the .001 per cent liquid spray. The data indicate that the effects of single applications of all materials began to run out 7 days after application. This has been observed (2) with McIntosh in New York State under similar weather conditions.

From the commercial standpoint, two applications of naphthalene acetic acid would have been justified on all McIntosh trees harvested after September 7 in this orchard. If color and maturity had permitted, it would not have been possible in 1942 to complete this harvest before September 12. The duplicate applications controlled drop quite satisfactory until all fruit was picked. The duplicate liquid spray of .0005 per cent concentration was about as effective as two applications of the 0.1 per cent dust. Batjer (1) has shown that the concentration of the spray might be reduced without seriously altering the results when the prevailing temperatures are high.

A similar test was conducted in a 35-year-old McIntosh orchard in western New York. Because of their greater age, these trees contained more weak wood than the younger trees used in the Hudson Valley test. The crop was quite uniform, but some variability in the nitrogen level as related to the carbohydrate supply was noted. This was exhibited as greener foliage and less mature fruit on some trees than on others. In general, however, the block was more vigorous and uniform than the average orchard of its age.

The dusts and sprays were applied on the morning of September 15. Starting at 7 a.m. when the temperature was 70 degrees F and the foliage was wet with a light dew, the dust treatments were made first followed by the liquid sprays which were completed about noon. The temperature rose throughout the forenoon, reaching a maximum of 90 degrees F at 3:00 p.m.

Ten trees were used in each treatment, five of which received a second application on September 18, with warm weather still prevailing. The fruit was picked on September 24 and 25. Table II gives the results.

TABLE II—EFFECT OF NAPHTHALENE ACETIC ACID SPRAY AND DUST ON THE DROPPING OF McINTOSH (FIRST APPLICATION SEPTEMBER 15; SECOND APPLICATION SEPTEMBER 18; FRUIT HARVESTED SEPTEMBER 24 AND 25)

Treatment	Number Applications	Cumulative Per Cent Drop—Original Crop*									
		Days After Spraying									
		1	2	3	4	5	6	7	8	9	10
Check	0	1.4	2.1	3.0	4.0	6.1	6.3	6.7	7.7	10.1	10.7
.001 per cent liquid spray	1	1.9	2.1	2.2	2.3	2.6	2.7	2.8	3.0	4.5	4.7
A-1 dust	1	1.3	1.6	1.9	2.0	2.9	2.9	3.1	3.4	—	—
A-2 dust	1	2.6	3.3	3.5	3.7	4.3	4.3	4.4	4.7	6.3	—
.001 per cent liquid spray	2	1.3	1.5	1.6	1.8	2.0	2.1	2.1	2.2	2.6	2.9
A-1 dust	2	1.9	2.3	2.6	2.8	3.3	3.4	3.4	3.6	4.4	—
A-2 dust	2	1.6	1.8	2.0	2.1	2.4	2.4	2.4	2.4	2.9	3.2
Temperatures	Sept 15	Sept 16	Sept 17	Sept 18	Sept 19	Sept 20	Sept 21	Sept 22	Sept 23	Sept 24	Sept 25
Maximum	90	86	88	85	88	67	64	75	70	74	64
Minimum	68	66	62	60	61	49	41	38	44	46	42

*Average of five trees per treatment, 27.3 bushels total yield per tree.

While both the initial and duplicate applications were made during a period of high temperatures on September 15 and 18, the weather changed on September 20 and much cooler conditions existed for the remainder of the pre-harvest period. The minimum temperaures after September 20 convey a more accurate idea of weather conditions than do the maximum temperatures. The temperature rose slowly each day and dropped rapidly after the maximum was reached.

The behavior of the check trees shows the effect of this change of weather on drop. These untreated trees dropped 6 per cent of their crop during the first 5 days of the test. After the on-set of cool weather there was relatively little drop until a moderately strong wind started on the afternoon of September 23. This lasted through the night and until noon on the following day. The wind was responsible for the slight but distinct increase in drop occurring between the eighth and ninth day of the test.

It might appear from the data that the single application of A-2 dust was not as effective in drop control as was the single applications of A-1 dust or the .001 per cent liquid spray. This was probably due to tree variability. It will be noted that the group of trees receiving the single application of A-2 dust were dropping the heaviest of any group at the beginning of the test. Three of these trees were located on a slight elevation and while they appeared to have an adequate supply of nitrogen, the proportion of carbohydrates to nitrogen was probably greater than for most other trees. This condition caused an advance in the maturity of the fruit by several days and suggests that the hormone might have been applied 3 or 4 days earlier on a few such trees. The duplicate application of the A-2 dust compares favorably with the duplicate applications of the other two materials.

Any additional benefit that these duplicate applications might have had over the single applications was masked by the cool weather. During the wind just prior to the first day of harvest, more apples fell from trees with single treatments than from those with duplicate treatments but the total amount in both cases was rather small.

Considering some variability among these 35-year-old trees as well as the interference with the rate of drop caused by the cool weather, there is nothing to indicate that either of these methods of applying the naphthalene acetic acid resulted in a more effective control of drop than the others.

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Effect of Preharvest Drop Sprays on the Storage Quality of Apples[1]

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AS THE growth regulating chemicals used in sprays to prevent preharvest drop, have powerful physiological effects on plant parts, it seemed likely that, when applied shortly before harvest, they might have a physiological effect on the fruit that would affect its storage quality. The use of the sprays might influence the storage quality in two ways: (a) a direct effect on the physiology of the fruit, and (b) an indirect effect due to more advanced maturity at later picking made possible by the sprays.

METHODS

In the 1939 harvest season Delicious, Rome Beauty, Stayman Winesap and York Imperial and in the 1940 season Jonathan, Starking, Stayman Winesap and York Imperial apples were obtained from experimental spray plots at Beltsville, Maryland. In 1939 the apples were given one application of an a-napthaleneacetic acid spray 1 to 2 weeks previous to picking at a concentration of .0005 per cent except that with the Delicious apples the spray was applied to the calyx and stem cavities only and a concentration of .002 per cent was used. In 1940 one application of .001 per cent was made to each variety. They were generally picked after considerable dropping from trees in the unsprayed plots had occurred, and in some instances two pickings were made. In 1939 the apples were packed with and without oiled paper and in 1940 with oiled paper in boxes and held at 32 degrees F until fairly late in their storage season. They were then post-ripened for a week at 70 degrees F and inspected for storage disorders. Pressure test determinations were made at harvest and after storage.

RESULTS

The preharvest spray did not affect the firmness at harvest or the rate of softening in storage as the average pressure test at harvest for 10 lots was 17.4 pounds for both sprayed and control apples and both averaged 13.5 pounds after storage, with eight comparisons. In two instances 0.25 and 0.50 per cent of summer oil was added to the sprays to increase their effectiveness. In both instances the apples sprayed with the a-napthaleneacetic acid and oil were appreciably softer both at harvest and after storage. The average pressure test at harvest was 16.3 pounds with oil and 17.9 without oil, and after storage the averages were 14.2 and 15.3 respectively. This indicates that an application of oil to the fruit near harvest time may advance the maturity or ripening of apples. However, the data are not conclusive in this respect.

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[1] Acknowledgment is made to L. P. Batjer, who furnished the apples for these investigations from his spray plots.

The application of the sprays had no effect on the susceptibility of the fruit to decay during storage (Table I) as there was an average of 5.4 per cent decay in 10 check lots and 4.4 per cent on comparable sprayed lots. The two lots sprayed with a-napthaleneacetic acid plus summer oil had appreciably and consistently more decay than the apples sprayed with a-napthaleneacetic acid alone (15.5 per cent with oil compared with 8.0 per cent without oil).

TABLE I—EFFECT OF A-NAPTHALENEACETIC ACID SPRAYS ON THE DEVELOPMENT OF DECAY DURING STORAGE AT 32 DEGREES F AND POST RIPENING AT 70 DEGREES F

Variety	Date Picked	Packed With Oiled Paper	Decay				
			Not Sprayed (Per Cent)	Sprayed With a-Napthalene-Acetic Acid (Per Cent)*		Sprayed With a-Napthalene-Acetic Acid +Oil (Per Cent)*	
Rome Beauty	Oct 16, 1939	Yes	5.8	—	—	—	—
	Oct 16, 1939	No	1.9	—	—	—	—
	Oct 27, 1939	Yes	6.6	5.3	7.4	11.1	5.2
	Oct 27, 1939	No	12.0	16.9	9.0	26.2	14.9
Stayman Winesap	Oct 28, 1939	Yes	4.6	1.8	—	—	—
Delicious	Oct 19, 1939	Yes	—	4.1	2.8	—	—
	Oct 19, 1939	No	—	14.0	7.3	—	—
York Imperial	Oct 28, 1939	Yes	3.0	5.1	—	13.0	—
	Oct 28, 1939	No	18.1	7.3	—	20.0	—
Jonathan	Sep 16, 1940	Yes	4.5	6.6	—	—	—
	Sep 26, 1940	Yes	15.0	11.1	—	—	—
Starking	Sep 17, 1940	Yes	2.6	2.6	—	—	—
	Sep 26, 1940	Yes	2.6	1.6	—	—	—
Stayman Winesap	Oct 15, 1940	Yes	2.0	2.1	—	—	—
	Oct 23, 1940	Yes	0.9	2.2	—	—	—
York Imperial	Oct 31, 1940	Yes	2.0	0.0	—	—	—

*The two columns represent replicate lots from different trees.

No appreciable amount of internal breakdown occurred except in the Jonathan apples. Somewhat more breakdown developed in the first than in the second picking of Jonathan and in both pickings the breakdown was greater in the unsprayed than in the sprayed apples (12.4 per cent in checks compared with 6.1 per cent in sprayed apples) as shown in Table II. However, the variability between replicate lots was as great as between the spray treatments so the difference between treatments was not statistically significant.

In the 1939 season the apples were packed with and without oiled paper but because of the late picking of most lots no scald developed even when no oiled paper was used. In the 1940 season all lots were packed with oiled paper and no scald developed except on the Starking lots. The sprayed lots averaged slightly more scald than the checks (13.6 versus 11.4 per cent) as shown in Table III, but the difference was not statistically significant because of much greater variability between lots from replicate trees.

Although no scald developed in the 1939-harvest fruit when no shredded oiled paper was used, it was observed that, with one exception, there was more decay in lots without the oiled paper than in comparable lots in which oiled paper was used at the recommended rate of ½ pound per bushel, as is shown in Table I. The average decay

TABLE II—EFFECT OF A-NAPTHALENEACETIC ACID SPRAYS ON THE DEVELOPMENT OF BREAKDOWN IN JONATHAN APPLES DURING STORAGE AT 32 DEGREES F AND POST RIPENING AT 70 DEGREES F

Tree Replicate	Breakdown	
	Not Sprayed (Per Cent)	Sprayed With a-Napthaleneacetic Acid (Per Cent)
Picked September 16, 1940		
1	18.6	4.9
2	10.9	6.8
3	27.7	9.4
4	2.7	—
5	17.9	—
Average	15.6	7.0
Picked September 26, 1940		
1	5.7	5.3
2	12.7	9.4
3	—	0.6
Average	9.2	5.1

TABLE III—EFFECT OF A-NAPTHALENEACETIC ACID SPRAYS ON THE DEVELOPMENT OF SCALD ON STARKING APPLES DURING STORAGE AT 32 DEGREES F AND POST RIPENING AT 70 DEGREES F

Scald					
Check* (Per Cent)			Sprayed With a-Napthaleneacetic Acid (Per Cent)*		
Picked September 17, 1940					
4.2	34.7	8.7	11.0	23.1	33.3
Picked September 26, 1940					
0	17.0	3.3	6.5	0.6	8.5

*The three columns represent replicate lots from different trees.

in all lots with oiled paper was 6.3 per cent, whereas without oiled paper it was 13.4 per cent or over twice as much. The mean difference was highly significant statistically. The reduction in decay did not appear to be due to the separation of the fruit by the paper, thus preventing the spread of decay from one fruit to another, as there was no apparent nesting or spread of decay between the apples in the check lots. Magness and Diehl (2) found that an oil coating on apples increased the CO_2 and reduced the O_2 in the internal atmosphere and retarded respiration and ripening of the fruit. They suggest that the oil in oiled wraps probably spreads to the fruit thus forming a thin oil coating. Thus the reduction in decay reported in this paper might be due to a higher CO_2 content in the internal atmosphere and retarded ripening resulting from the use of oiled paper, as suggested by Magness and Diehl. This interpretation is in agreement with the results reported by Kaess (1) and Scupin (3) who observed a reduction in decay in apples coated with oil, but is contrary to the results obtained when oil was used in the hormone sprays 2 to 3 weeks previous to harvest. If the results for one season reported herein are borne out by further studies they would suggest the use of oiled paper for the control of decay as well as for scald.

SUMMARY

Storage tests of six varieties of apples given pre-harvest sprays of a-napthaleneacetic acid to delay dropping did not show any direct effect of the sprays on the firmness of the apples or the development of decay, breakdown, or scald during storage when compared with unsprayed apples picked at the same time. An indirect effect on storage quality, due to more advanced maturity at later picking made possible by the sprays, may result.

Limited results indicated that softer fruit more subject to decay may result from the addition of 0.25 to 0.50 per cent of summer oil to the pre-harvest sprays.

An appreciable reduction in decay was observed when the apples were packed with shredded oiled paper.

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Three-Year Study of Preharvest Sprays in Washington[1]

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DURING the past three seasons the use of growth promoting chemicals to control preharvest fruit drop in Washington has developed from the experimental stage to the point where many growers consider it as one of the standard orchard practices.

Object of Experiments

These experiments herein reported were designed to study the effectiveness of the alpha naphthaleneacetic acid spray in controlling fruit drop as related to: (a) concentration of the chemical in the spray; (b) the addition of spreader, oils, lead arsenate, and certain safeners for lead arsenate, (zinc sulfate and lime); (c) the temperature at time of and following application of the spray; (d) simulated rainfall following application of the spray; and (e) repeat applications. The period of effectiveness of the spray and the possible effect on fruit maturity were also included in this study.

Methods of Procedure

In some of the experiments entire trees were sprayed whereas in others only half-trees were used. With the latter, a string divided each tree into two parts, usually on a north-south line, using when feasible, natural divisions. A different treatment was given each half-tree, and the dropped as well as the harvested fruit from each half was segregated and counted.

By using half-trees instead of entire trees as a basis for comparison between treatments, less trees were necessary since the variation between the dropped fruits on different sides of the same tree was usually less than between adjacent trees. With careful division of the trees and application of the spray on quiet days, there was little spray drift from one side of the tree to the other. In most instances, the spray was applied as the fruit began to show signs of dropping. The dropped fruit was collected every 2 to 3 days up to the time of harvest and the total per cent drop figured on the basis of the number of apples on the tree at the time the experiments were started.

In evaluating the data, not only the average drop for the several half-trees of each treatment but also the relative differences between treatments on the two halves of the same tree were considered. That the spray on one-half of a tree did not materially affect the fruit on the other half was evidenced by the rather marked differences in drop between halves of a tree, one side of which was sprayed, and the other side unsprayed.

Presentation of Data

Effectiveness of Sprays:—Presented in Table I are data from experiments in which a solution of 10 parts per million of alpha naphtha-

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TABLE I—FRUIT DROP OF APPLES AND PEARS AS INFLUENCED BY APPLICATION OF ALPHA NAPHTHALENEACETIC ACID SPRAY (10 PARTS PER MILLION + SPREADER OR OIL)

Location	Variety	Number of Trees		Maximum Temperature† Days After Application (Degrees F)					Date of Spray	Date of Harvest	Drop, Sprayed Trees (Per Cent)	Drop, Unsprayed Trees (PerCent)	Year
		Sprayed	Unsprayed	0	1	2	3	4					
						Apples							
Grandview	Delicious	3	3	85	90	91	82	92	Sep 7	Sep 18	16.6	27.7	1940
Grandview	Winesap	5	3	78	80	76	74	74	Sep 16	Sep 29	9.1	12.9	1940
Prosser*	Jonathan	2 (½)	2 (½)	80	88	84	88	70	Aug 23	Sep 15	39.0	42.5	1940
Wenatchee	McIntosh	4	6	91	97	97	95	96	Aug 16	Sep 4	13.6	37.5	1940
Wenatchee	Delicious	3	2	76	71	74	78	68	Aug 30	Sep 20	4.7	22.1	1940
Wenatchee	Jonathan	18	4	70	77	74	70	73	Aug 28	Oct 3	1.8	3.2	1941
Wenatchee	Winesap	11	9	83	81	68	72	63	Sep 24	Oct 10	2.0	15.7	1941
Wenatchee	Delicious	4 (½)	5 (½)	69	67	67	69	68	Sep 13	Sep 25	6.6	13.0	1941
Wenatchee	McIntosh	8	3	93	95	91	81	79	Aug 20	Sep 2	9.2	16.6	1941
Wenatchee	Delicious	4 (½)	4 (½)	73	78	80	81	83	Sep 18	Oct 16	4.8	23.1	1942
Wenatchee	Winesap	2 (½)	2 (½)	74	72	67	72	76	Oct 6	Nov 5	12.8	54.0	1942
						Pears							
Husum‡	Bosc	12	3	81	83	67	67	72	Sep 11	Sep 22	1.8	13.9	1940
Husum‡	d'Anjou	4	3	81	83	67	67	72	Sep 11	Sep 22	1.1	2.0	1940
Husum	Bosc	8	11	67	72	71	70	63	Sep 14	Sep 30	6.9	18.7	1940
Husum	d'Anjou	4	4	67	72	71	70	63	Sep 14	Sep 30	1.0	1.2	1940
Wenatchee	Bartlett	½	½	88	87	90	94	98	Aug 11	Aug 28	5.4	18.2	1942

*Five parts per million applied with a knapsack sprayer to fruits and not foliage.

†Taken from nearest weather station records.

‡Five parts per million.

leneacetic acid with spreader or ⅛ per cent oil was applied. The maximum temperature, date of spray, date of harvest, and per cent drop on sprayed and unsprayed trees, as well as variety and location are given.

These data show the effectiveness of the spray in controlling fruit drop with several varieties of apples and pears. With only a few exceptions, the applications of the growth chemical sprays materially reduced the fruit drop. The exceptions were with the Jonathan variety at Prosser in 1940, in which case the application was at the relatively low concentration of 5 parts per million, to the fruits only, and possibly with Jonathan at Wenatchee in 1941 and with Beurre d'Anjou pears at Husum in 1940. In these last two instances, the drop from unsprayed trees was so small that only slight differences between drop from sprayed and unsprayed trees were recorded.

The drop of Delicious at Wenatchee in 1941 was not as effectively controlled as was the fruit drop of this variety in 1940 and 1942. The application in 1941 was at a time when the weather was cool (maximum temperature below 70 degrees F) and rainy, and the drop was reduced from 13 on unsprayed to 6.6 per cent on sprayed trees. In 1940 and 1942, with temperatures above 70 degrees at the time of application, the reduction in fruit drop was considerably greater (see Table IV). This reduction in fruit drop was from 22.1 per cent on unsprayed trees to 4.7 per cent on sprayed trees in 1940, and from 23.1 to 4.8 per cent in 1942. In 1942 this reduction in drop occurred over a period of almost a month.

With the data in Table I, however, it is difficult in some other cases to correlate effectiveness of the spray with temperature at the time of and following the application. There are wide variations in interval of time between spray application and date of harvest, which in itself, may have more total effect than the temperature. Nevertheless, the preharvest drop of the McIntosh was more effectively controlled in 1942 when the maximum temperatures during the first 4 days following spray application were somewhat higher than during 1941. Furthermore, with the Winesap the spray in 1941 seemed to be more effective when the maximum temperatures were higher on the date of application and for the first 2 days thereafter than was the case in 1942.

The data show that with Delicious, Winesap, McIntosh apples and Bartlett and Bosc pears, alpha naphthaleneacetic acid sprays, when applied under favorable conditions, effectively controlled preharvest fruit drop. These conditions include warm, sunny weather, adequate concentration and coverage, proper timing, and healthy trees (11).

Concentration of Chemical:—In commercial use, the alpha naphthaleneacetic acid has been applied mostly at a concentration of 10 parts per million. There have been applications, however, at a concentration below 10 parts per million. The literature is somewhat contradictory as to the effect of reducing the concentration of alpha naphthaleneacetic acid to below 10 parts per million. Some reports indicate that a reduction in concentration to below 10 parts per million has lowered the effectiveness of the spray in reducing fruit drop, (4, 6, 8, 10, 12) whereas others have indicated that concentrations below 10 parts per million were equally effective (6, 9).

The influence of lowering the concentration to 3 and 6 parts per million in comparison with 10 parts per million on the fruit drop in these experiments is, shown in Table II.

TABLE II—THE RELATION OF CONCENTRATION OF ALPHA NAPHTHALENEACETIC ACID TO THE EFFECTIVENESS OF THE SPRAY IN OPPOSING PREHARVEST FRUIT DROP (1941)

Concentration of Naphthaleneacetic Acid (With ⅛ Per Cent ,Oil) (Ppm)	Number of Half-Trees	Average Number Fruits Per Half-Trees	Average Number Drops Per Half-Trees	Average Drop (Per Cent)
Delicious—Sprayed September 13—Harvested September 25				
10	4	1,607	106	6.6
6	5	1,341	116	8.7
3	5	1,273	127	10.0
Unsprayed	5	1,491	195	13.0
Winesap—Sprayed September 24—Harvested October 13				
10	3	1,820	40	2.2
6	5	1,379	130	9.4
3	3	1,650	153	9.3
Unsprayed	3	1,357	233	17.2

Concentrations of 3 and 6 parts per million were not as effective in controlling fruit drop as were concentrations of 10 parts per million of alpha naphthaleneacetic acid. The drop with Delicious was 10.0 per cent and 8.7 per cent with 3 and 6 parts per million respectively, and only 6.6 per cent with a concentration of 10 parts per million. Whereas a concentration of 10 parts per million reduced the Winesap drop to 2.2 per cent, concentrations of 6 and 3 parts per million reduced the drop to only 9.4 and 9.3 per cent respectively.

These data suggest that if maximum reduction in preharvest drop is to be obtained, the concentration should not be reduced below 10 parts per million.

Value of Stickers, Spreaders and Safeners:—Small increases in effectiveness of preharvest sprays have been obtained by the use of oil or spreader (4, 12). The spreader or oil may provide a more uniform wetting and possibly a more complete penetration of the chemical. Lime has been found to reduce the effectiveness of the preharvest spray (7).

Various concentrations of oil, spreader, zinc sulfate and/or lime were applied with alpha naphthaleneacetic acid to determine the influence of these materials on the effectiveness of the growth chemical spray in reducing fruit drop. These data are presented in Table III.

The 1941 data with the Winesap indicate that a small increase in effectiveness of the spray resulted from the addition of ⅛ per cent oil or the use of spreader. There was a marked reduction in fruit drop with all sprayed trees, with only slight differences between the drop from trees receiving alpha naphthaleneacetic acid alone, or with oil or spreader.

With Delicious in 1942, the alpha naphthaleneacetic acid was applied with 1 per cent and ⅛ per cent oil, and with ¼ per cent oil

TABLE III—THE INFLUENCE OF OIL, SPREADER, ZINC SULFATE, AND LIME ON EFFECTIVENESS OF ALPHA NAPHTHALENEACETIC ACID SPRAYS

Alphnaphthalene Acetic Acid (10 Ppm)	Number of Half Trees	Number of Apples Per Half-Tree	Drops Per Half-Tree	Average Drop (Per Cent)
Winesap—Sprayed September 24, 1941—Harvested October 11				
Vatsol (1–5000)	5	1,682	41	2.4
⅛ per cent oil (50–55 visc. 92 U. R.)	5	2,076	55	2.6
No spreader	5	2,200	71	3.2
Unsprayed	5	1,353	208	15.4
Delicious—Sprayed September 18, 1942—Harvested October 16				
⅛ per cent oil (50–55 visc. 92 U. R.)	4	1,379	66	4.8
1 per cent oil (50–55 visc. 92 U. R.)	3	2,059	51	2.5
¼ per cent oil (50–55 visc. 92 U. R.) + 3 lbs. lead arsenate	3	1,165	39	3.3
Unsprayed	4	1,286	293	23.1
Winesap—Sprayed October 6, 1942—Harvested November 5				
⅛ per cent oil (50–55 visc. 92 U. R.)	2	1,940	248	12.8
¼ pound Zn.S.O.$_4$ per 100 gallon	2	1,961	150	7.7
½ pound lime per 100 gallon	2	1,851	276	14.9
¼ pound Zn.S.O.$_4$ + ½. pound lime per 100 gallon	2	2,528	203	8.0
Unsprayed	2	2,031	1,098	54.0

and 3 pounds of lead arsenate per 100 gallons. All three sprays effectively reduced the fruit drop over a period of a month, the drop being 4.8, 2.5, and 3.3 per cent for each treatment respectively in comparison with 23.1 per cent from unsprayed trees.

The 1942 experiments with Winesap were conducted to determine the influence of lime and zinc sulfate, safeners used for arsenate of lead, on the effectiveness of the growth chemical spray in controlling the fruit drop. A very severe drop of 54 per cent occurred from the unsprayed trees, whereas the trees receiving the alpha naphthaleneacetic acid spray with oil, dropped only 12.8 per cent of the fruit. The addition of lime alone seemed to slightly reduce the effectiveness of the spray, the trees receiving this treatment dropping 14.9 per cent of the fruit. Trees that received alpha naphthaleneacetic acid and zinc sulfate with and without lime, had the smallest fruit drop, 8.0 and 7.7 per cent respectively. This may indicate that the zinc sulfate actually increased the effectiveness of the spray.

Temperature:—The possibility of temperature influencing the effectiveness of alpha naphthaleneacetic acid sprays in controlling fruit drop has been suggested (3, 4, 5, 10). Batjer (1) found that sprays applied at midday, when temperatures were relatively high, were more effective than when applied in early morning with cooler conditions. Variable results heretofore reported in many instances may have resulted, at least partially, from differences in temperature at the time of and subsequent to the application of the spray. Experiments were conducted to determine the influence of time of application as related to temperature upon the effectiveness of the spray in reducing preharvest fruit drop as shown in Table IV.

TABLE IV—INFLUENCE OF TEMPERATURE AT TIME OF AND SHORTLY AFTER APPLICATION ON EFFECTIVENESS OF ALPHA NAPHTHALENEACETIC ACID IN CONTROLLING FRUIT DROP (1942) (10 PARTS PER MILLION + 1 PINT OIL; DELICIOUS APPLES SPRAYED SEPTEMBER 19, HARVESTED OCTOBER 16)

Time of Spray	Temperature (Degrees F) Days After Application							Number Half Trees	Average Number Apples Per Half-Tree	Average Number Drops Per Half-Tree	Average Drop (Per Cent)
	0	1	2	3	4	5	Av.				
7 a.m.	42	48	56	60	64	68	56	5	1,429	88	6.2
1 p.m.	75	78	76	74	70	66	73	3	1,348	45	3.3
7 p.m. . . .	61	56	53	52	50	49	54	3	1,400	73	5.2
Unsprayed .	—	—	—	—	—	—	—	3	1,247	317	25.4

Sprays were applied at 7 a.m., 1 p.m., and 7 p.m. and the possible relationship of the temperature prevailing at the time of, and for the few hours after the application to the effectiveness of the spray was noted.

Whereas all sprays were effective in reducing fruit drop, the spray applied at 1 p.m., when the temperature was 75 degrees F, was most effective. The drop from these trees was 3.3 per cent as compared with 5.2 per cent for the trees sprayed at 7 p.m. when the temperature was 61 degrees F, and 6.2 per cent for the trees sprayed at 7 a.m., with a temperature of 42 degrees F. These data indicate that sprays applied during the warm part of the day were more effective than when applied during the early morning or late evening.

It should be pointed out that the temperature prevailing 4 to 5 hours after spray application, as well as at the time of application, may be relatively important in determining the ultimate effectiveness in controlling fruit drop. As shown in Table IV, the average temperature for the first 5 hours following the morning and evening applications was approximately the same, 56 degrees F and 54 degrees F. The fruit drop from trees in these plots was as heretofore stated, 6.2 and 5.2 per cent. With trees sprayed at 1 p.m., however, the average temperature was 73 degrees F for the 5 hours following the application. The fruit drop from these trees, as compared with trees sprayed in early morning and late evening, was considerably lower, it being only 3.3 per cent. Hence, the best results were obtained when the temperature was relatively high at the time of and following spray application. While data are limited, they do suggest that a spray is more effective if applied when the temperature is relatively high even though subsequently, temperatures may become lower, than to apply when temperatures are relatively low followed by rising temperature.

The relatively effective control of preharvest fruit drop with trees sprayed in the morning or evening at low temperatures in 1942, as contrasted with the relatively poor control in 1941, may possibly be explained by the fact that in 1942, whereas the temperature at time of application was low, the maximum temperatures for the several days following application were considerably higher than in 1941 (Table I).

The Effect of Rains:—The possible effect of rain following the application of alpha naphthaleneacetic acid sprays on its effectiveness is also of interest. To simulate rain, heavy water spray applications were made to trees 2, 8, and 24 hours after an application of the growth chemical spray. These data are presented in Table V.

TABLE V—EFFECT OF WATER SPRAY APPLICATIONS TO SIMULATE RAIN 2, 8, AND 24 HOURS AFTER AN APPLICATION OF ALPHA NAPHTHALENEACETIC ACID (10 PARTS PER MILLION) ON THE PREHARVEST DROP OF DELICIOUS APPLES (SPRAYED SEPTEMBER 19, HARVESTED OCTOBER 16, 1942)

Treatment	Number Half Trees	Average Number Apples Per Half-Tree	Average Number Drops Per Half-Tree	Average Drop (Per Cent)
No water	3	1,083	86	7.9
Water after 2 hours	3	1,075	144	13.4
Water after 8 hours	2	1,105	82	7.4
Water after 24 hours	2	1,112	100	9.0
Unsprayed	3	1,247	317	25.4

The only serious decrease in effectiveness occurred when the water spray was applied 2 hours after the alpha naphthaleneacetic acid spray. These trees dropped 13.4 per cent of the fruit as contrasted with a drop of 25.4 per cent for trees not receiving the alpha naphthaleneacetic acid spray and 7.9 per cent for trees receiving no water spray following the growth chemical spray. Water sprays 8 and 24 hours following growth chemical application apparently did not adversely influence the effectiveness of the alpha naphthaleneacetic acid spray since the fruit drop from these trees was 7.4 and 9.0 per cent respectively.

Repeated Spraying and Period of Effectiveness:—Experiments (10, 11) have shown there is little benefit from the application of repeat sprays of growth chemicals as shown in Table VI.

TABLE VI—INFLUENCE OF REPEAT APPLICATIONS UPON THE EFFECTIVENESS OF ALPHA NAPHTHALENEACETIC ACID (10 PARTS PER MILLION) IN CONTROLLING PREHARVEST DROP OF McINTOSH APPLES (1940)

Dates Sprayed	Number of Trees	Average Number Apples Per Tree	Average Drop (Per Cent)	
			Aug 16 to Aug 28	Aug 16 to Sep 4
Aug 16	3	2,049	4.0	15.8
Aug 16 and Aug 28	3	2,370	7.9	17.7
Unsprayed	4	1,750	21.6	49.6

The data in Table VI show that with the three trees receiving only one spray the average percentage of preharvest drop was slightly less than that of the three trees receiving an additional spray 12 days later. The period of effectiveness may vary from 11 to 12 days with McIntosh to as long as 21 to 28 days with the Winesap and Delicious. If the temperatures during the days following the spray application are relatively cool, the period of effectiveness tends to be more prolonged than if warm weather prevails.

Effect on Maturity and Storage Capacity:—Observations have indicated that the growth chemical sprays have little effect on fruit maturity, either before harvest, or in storage after harvest, so long as the fruit is harvested at the proper stage of maturity.

SUMMARY

Alpha naphthaleneacetic acid sprays at a concentration of 10 parts per million have effectively reduced the preharvest fruit drop of Delicious, Winesap and McIntosh apples and Bosc, and Bartlett pears.

Reducing the concentration of alpha naphthaleneacetic acid to 6 and 3 parts per million has reduced the effectiveness of the spray.

The addition of spreaders and oil have not greatly increased the effectiveness of the growth chemical spray. Lime applied with alpha naphthaleneacetic acid sprays has reduced the effectiveness, whereas the addition of zinc sulfate may have increased the effectiveness.

Applications during the warm part of the day have more effectively reduced drop than have applications made in early morning or in late evening, when the temperatures were relatively low.

Spraying of water on trees 2 hours following spray of alpha naphthaleneacetic acid materially reduced the effectiveness of the spray whereas water sprays after 8 and 24 hours had no effect.

Little benefit was obtained from successive applications of the growth chemical sprays.

The period of effectiveness of any one application may vary from 11 to 12 days with McIntosh and 21 to 28 days with the Delicious and Winesap. The period of effectiveness tends to be longer when cool weather follows the spray than when warm weather prevails.

Observations have indicated that alpha naphthaleneacetic acid sprays do not affect the fruit maturity at the time of harvest or rate of ripening, either before the fruit is harvested, or in storage so long as the fruit is picked at the proper stage of maturity.

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The Relation of Size of McIntosh Flower Buds to the Production of Fruit[1]

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THE noticeably small size of flower buds on apple trees growing in Vermont compared with the size of flower buds of the same varieties growing further south prompted a study of the performance in Vermont of various sizes of dormant season McIntosh spur buds.

Other workers (1, 2, 3) have shown that blossom bud formation and set of fruit is related to spur growth, spur size and spur performance in the previous season. This paper indicates that the diameter of the terminal spur bud may also be used as an index of potential fruit production.

The diameter of terminal spur buds is a simple measurement to make and it may be obtained any time from late July until the buds begin to swell the following spring. Once the ideal flower bud size for the variety has been fixed in mind, it is not necessary to make measurements for comparative purposes.

Materials and Methods

Twenty-five fairly uniform McIntosh apple trees, set in 1930, were used for this study. The diameters of 10 spur buds on each of three vigorous branches on each tree, 750 in all, were measured after leaf fall with a vernier caliper and the buds tagged and numbered. The bloom data were recorded in May of 1939, and the records on mature fruit were taken at the time of harvest. The same procedure was followed on buds produced in 1939 except that only 450 buds on 15 trees were measured and marked.

The buds were arbitrarily divided into four size groups. The largest,

TABLE I—Performance of McIntosh Spur Buds in 1939 and 1940 According to Size of Bud

Bud Class and Size (Millimeters)	I 4.6 and over	II 4.1 to 4.5	III 3.6 to 4.0	IV 3.5 and under
1939				
Number of buds	120	230	129	32
Per cent of total buds	24	45	25	6
Number to bloom	120	230	126	28
Per cent to bloom	100	100	98	88
Number buds maturing fruit	64	100	37	4
Per cent of buds maturing fruit	53	43	29	13
1940				
Number of buds	1	10	108	290
Per cent of total buds	—	3	26	71
Number to bloom	1	7	35	35
Per cent to bloom	100	70	32	12
Number buds maturing fruit	1	4	25	24
Per cent of buds maturing fruit	100	40	23	8

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called Class I, were 4 millimeters or more in diameter; Class II were 4.1 to 4.5 millimeters; Class III, 3.6 to 4.0 millimeters; and Class IV, the smallest buds, were 3.5 millimeters and under in diameter at the widest point.

Data could not be secured on all of the buds originally marked because some of the identification tags became dislodged. The results recorded are based on the number of identifiable tags at the close of each period.

RESULTS

The performance of the tagged buds is set forth in Table I.

The mean average yield per tree in 1939 was 135 ± 45.5 pounds; in 1940 it was only 39.4 ± 17.5 pounds.

The trend of the larger buds to produce more fruits is shown by the regression line in Fig. 1.

DISCUSSION

A direct relationship existed between size of spur buds and fruit production. In 1939, 69 per cent of the buds were in Classes I and II, whereas in 1940 less than 4 per cent of the buds were in these two classes.

When the data were subjected to an analysis of variance, the difference in performance between the larger and smaller bud sizes was found to be highly significant in both seasons. In 1939, buds in Classes I and II matured 19 per cent more fruits than buds in Class III and 35 per cent more than those in Class IV. Class III buds produced 16 per cent more fruit than Class IV buds.

In 1940, the bulk of the buds fell in Classes III and IV and again the Class III buds produced 15 per cent more fruit than those in Class IV.

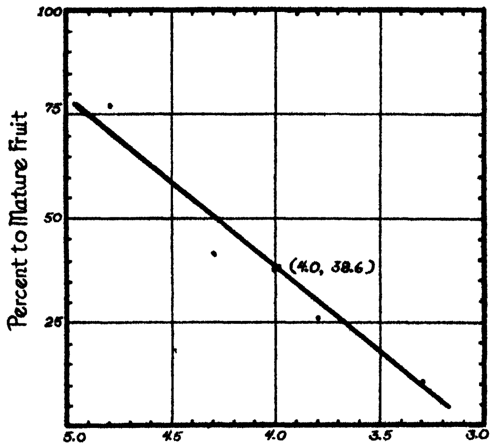

FIG. 1. Regression of percentage of buds to mature fruit on size of buds. Bud Size (Mm.)

The size of the flower buds is an indication of tree vigor and may be used in conjunction with trunk size as a reliable index of fruit yield. Information on flower bud size may also be a helpful guide in formulating orchard management practices. If a grower knows that a high percentage of the buds that bloomed were of large size, he may be reasonably assured that a high percentage of them will fruit whereas if the buds were small, even though the trees bloom abundantly, he may expect only a small percentage of them to mature fruits.

SUMMARY

Data on the performance of terminal buds of McIntosh spurs in 1939 and 1940 indicate that the larger buds matured a significantly higher per cent of fruits than did the smaller buds.

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Studies on the Growth Status of Delicious, Baldwin and Stayman Winesap Apples

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MANY papers have been published within recent years dealing with the growth expression of fruit trees. Horticulturists find certain quantitative measurements of value in interpreting experimental results and in regulating commercial orcharding practices. Numerous indeces have been used, including increase in trunk circumference, increase in length of stem, root or shoot, increase in leaf area, increase in volume (generally of fruit), and dry and fresh weight increments. But still there is no entirely satisfactory quantitative method for measuring both the relative vegetative and the reproductive conditions of fruit trees. The literature on this work is reviewed by Blake and Davidson (1), Harley (2), Magness, Overley, and Luce (3), Potter Kraybill, Wentworth, Sullivan, and Blood (4), Roberts (5), Vyvyan and Evans (6), Wilcox (7), and other investigators have included measurements of leaf area per spur or shoot, increase in terminal growth, relation between length and width of leaves and many others.

In planning this study several of these criteria as well as the value of spur diameter measurements have been used in an attempt to evaluate their application to strikingly different growth conditions on Delicious, Baldwin and Stayman Winesap apples. Four plots of Delicious apple trees were selected arbitrarily on the basis of their known treatment and performance as follows: Two of the experimental treatments were in Orchard C at the Ohio Agricultural Experiment Station. This orchard was planted in 1915 and half the trees have been in continuous cultivation with two cover crops each year. The other half of the orchard was planted to bluegrass sod, and has been continuously in the straw mulch system. The other two experimental treatments were selected in the Melrose orchard at Wooster and consisted of a plot of mature trees in a bluegrass sod where the trees had a sparce growth so that one could look through the trees. On the second plot the trees for the last three years have received moderate annual applications of straw mulch and the ground was dense and the leaves deep green in color. Both plots have been receiving annual applications of 4–10–6 fertilizer.

Another set of trees included Baldwin and Stayman Winesap varieties in Orchard J at the Ohio Agricultural Experiment Station. These trees were planted in 1922 and were growing in sod. The plots were receiving various fertilizer treatments as follows: Triple nitrogen, normal nitrogen, complete, normal nitrogen and phosphorous, normal nitrogen and potash and untreated trees. Here it was designed to determine if an appreciable difference would be shown by the measurements taken to verify the total growth difference noticeable in the field.

The measurements consisted of three types, namely, total leaf area per spur in square centimeters, relative spur diameters and the length and width of each leaf. This latter measurement is expressed as a ratio in per cent by dividing the length of the leaf blade by the width. These leaf ratios were calculated to see if a possible relationship existed with vigor and quality of growth. Previous studies have indicated this correlation (1). Leaf area per spur was accurately determined by using an Aminco photo area measuring instrument. Growths over 2 inches long were considered to be shoots rather than spurs. Spur diameters were carefully calipered at the base of the current season's growth.

The method of sampling involved a close consideration of the tree under study, requiring careful observation and judgment with impartiality in evaluating the relative growth condition. Samples of 10 spurs each were selected representing the typical type present. These were selected from the periphery of the tree as far up from the ground as the worker could reach. This sampling was repeated at 10 different intervals approximately 1 week apart, thus giving 10 replications which would indicate the accuracy of the sampling technique. Measurements did not begin until the measured leaves were fully expanded.

Selection of spurs was further segregated on the type of blooming condition. These were divided into three classes as follows: Those not blooming the current season, those blooming but not fruiting, and spurs blooming and fruiting. Similar measurements were made on the Baldwin and Stayman Winesap trees except that here attention was also given to the biennial bearing habit; that is, whether the tree was in its "on" or "off" year.

RESULTS

The accumulated data for the four plots of Delicious trees growing in heavy mulch and those in cover crop culture (Orchard C) is represented in Table I. Referring to the table it can be clearly seen that there is an appreciable difference apparent in the treatments and also between types of spurs. Trees in both orchards received normal annual applications of nitrogen fertilizer at the rate of ¼ pound of nitrate of soda for each year of the tree's age. The cover crops grown in the one plot were disced under. The values represent each type of spur condition under both treatments and the respective values for the 10 replications.

TABLE I—COMPARISON OF GROWTH MEASUREMENTS OF DELICIOUS APPLES, STRAW MULCH AND COVER CROP CULTURE (ORCHARD C — 1941)

Material	Old Straw Mulch			Cover Crop Culture		
	Leaf Ratio	Leaf Area (Cm²)	Spur Diameter (Cm)	Leaf Ratio	Leaf Area (Cm²)	Spur Diameter (Cm)
Non-blooming spurs	51.57	76.91	0.407	57.03	53.89	0.362
Blooming non-fruiting spurs . . .	57.99	57.23	0.359	61.16	41.00	0.325
Fruiting spurs . . .	62.96	42.31	0.333	64.569	33.70	0.304

It should be noted that each individual set of data represents the average of 10 spurs, and thus the mean averages are derived from groups of 10 spurs, with the total mean average representing 100 spurs. Here may be seen the close approximation in values between the replicates. It is interesting to note that the extremes in the range of values do not deviate appreciably from the mean average. Therefore, it tends to substantiate the reliability in the method of selecting typical spurs. It has long been known that the presence of developing flowers or a developing apple restricts the growth of spur leaves. Potter (4) points this out clearly in his paper on some effects of defloration on fruit spur composition and fruit bud formation. In this respect, the data on Table I further substantiate this viewpoint. Appreciable differences may be noted between leaf areas and spur diameters for the three classes of spurs. Similarly, the leaf ratios tend to increase as there is a transition from a vegetative to a reproductive condition, thus giving consistent support to conclusions advanced by earlier workers using various growth measurements. After examining the values from the two plots in Table I, it is apparent that an appreciable difference exists in the values between the plots. This validates the pronounced growth difference in total tree growth as observed in the orchard. The trees under the straw mulch had dark green leaves, were dense, more upright and in a generally vigorous condition. The trees in the cover crop culture, on the other hand, were a lighter green, had smaller leaves, were not as dense and the growth was more spreading rather than erect. The fruits were smaller and deeper red in color indicating presumably that a difference in carbohydrate-nitrogen relationship existed.

Table II lists the data as analyzed from measurements taken in the Melrose orchards at Wooster, Ohio, for well matured Delicious apple trees. The trees had been growing in sod and one group of trees had only been mulched the last three years, while the second plot was growing in continuous bluegrass sod culture. The unmulched trees were decidedly low in vigor even though they have been well fertilized. Trees of Delicious have this characteristic tendency. These data reveal that considerable differences exist for the two treatments and among the three spur types. An exception is to be noted in that the trees in the plot under continuous sod culture with relatively low vigor do not show the same differences in leaf ratios. These trees had leaves with the highest ratio percentage of all treatments. Data found for the mulch plot does not give the typical relationship for leaf areas per spur and values for spur diameters.

TABLE II—COMPARISON OF GROWTH MEASUREMENTS OF DELICIOUS APPLES UNDER THREE-YEAR STRAW MULCH AND SOD CULTURE (MELROSE ORCHARDS — 1941)

Material	Three-Year Straw Mulch			Sod Culture		
	Leaf Ratio	Leaf Area (Cm^2)	Spur Diameter (Cm)	Leaf Ratio	Leaf Area (Cm^2)	Spur Diameter (Cm)
Non-blooming spurs	51.94	102.59	0.415	60.68	58.26	0.368
Blooming non-fruiting spurs........	54.13	80.72	0.342	38.36	40.56	0.327
Fruiting spurs......	61.75	55.58	0.299	60.83	30.76	0.274

Data showing the influence of fertilizer treatments on Stayman Winesap apple trees in Orchard J at the Ohio Agricultural Experiment Station are presented in Table III. These trees are well matured and have a pronounced biennial bearing habit established. Similarity between the respective values for the replications is apparent, such as in the normal nitrogen trees. It is worthy of note that these trees had the largest leaf areas per spur over that of other treatments. Another interesting deduction can be obtained from the triple nitrated trees. Although the trees appear dense and have deep green foliage — the total leaf area per spur is less than on any other fertilizer treatment except the check which had no fertilizer applied. Also a pronounced difference exists between the "on" and "off" year for spur development. It is apparent that in the "off" year, larger spurs were developed and they also had greater leaf area per spur. The most pronounced difference seemed to be in the diameter of the spur, followed in order next by the increase in leaf area, while ratios were only slightly affected.

From Table IV similar results were obtained. The variety studied was Baldwin. These data again suggest that the normal nitrogen plots appear more favorable in relation to leaf area and spur diameter than the unfertilized one. The trees receiving the triple nitrogen applications had less leaf area per spur and a smaller diameter of spur wood than any of the fertilizer treated plots and only exceeded the check trees receiving no fertilizer. Here also, no appreciable differences were observable in relative leaf ratios. The increase in leaf area and spur diameter is again evident in the trees during their "off" year of bearing.

DISCUSSION

It has long been known that differences in growth exist between fruit trees, but it has not always been clear as to what would be the most reliable index to measure this variation. When a consideration of the quality of growth is also considered a complex situation is involved. Numerous types of measurements of vigor have been made of different kinds of tree growth and yet there still does not appear to be any one index for tree vigor that is infallible. The method of sampling is the crux of the entire problem. Such a diversity of types of spurs and shoots are situated on a single branch and the multitude of variation between branches makes impossible the selection in systematic fashion within the realm of practicality. Blake (1) has previously shown that arbitrary selection is of definite value. Data presented herein further indicate rather consistent accuracy obtainable by critical sampling through the selection of index spurs for a given tree. Certain previous workers have at times neglected to give attention to the type of spur selected thus rendering their conclusions difficult to apply. From the differences noted in various studies, it appears imperative that detailed consideration be given to the type of spurs selected.

The influence of the biennial bearing habit on leaf areas per spur and spur diameters was clearly shown from an analysis of the data.

TABLE III—COMPARISON OF GROWTH MEASUREMENTS OF STAYMAN WINESAP APPLES UNDER VARIOUS FERTILIZER TREATMENTS (ORCHARD J—1941) ALL SPURS NON-BLOOMING, SOD CULTURE

	Triple Nitrogen			Normal Nitrogen			Complete Fertilizer			Normal Nitrogen		
	Ratio	Area†	Diameter‡	Ratio	Area	Diameter	Ratio	Area	Diameter	Ratio	Area	Diameter
1.	59.28	90.35	0.359*	56.98	120.00	0.392*	54.54	107.50	0.380*	56.25	116.65	0.423*
2.	55.65	90.85	0.363*	58.61	126.10	0.399*	56.72	10.375	0.380*	56.60	120.80	0.397*
3.	59.20	96.20	0.358	56.43	114.35	0.385	53.76	106.80	0.382	53.59	113.35	0.398
4.	59.82	89.55	0.361	55.40	84.00	0.358	54.82	103.25	0.377	56.15	123.30	0.380
5	57.96	88.55	0.371	61.29	117.90	0.392	56.35	105.50	0.375	54.91	120.80	0.397
Total mean average	58.382	91.10	0.3624	57.742	112.48	0.3852	55.238	105.36	0.3788	55.500	118.98	0.3990
	Normal N and P			Normal Nitrogen			Normal N and K			Normal Nitrogen		
1.	53.32	105.55	0.400*	52.82	113.45	0.396*	60.39	105.60	0.402*	61.58	114.05	0.387*
2.	56.98	106.70	0.404*	56.48	113.80	0.401*	54.75	94.25	0.395*	55.08	114.25	0.396*
3.	57.11	105.15	0.399	54.84	118.00	0.399	52.90	95.40	0.389	54.48	110.50	0.396
4.	55.59	106.55	0.401	54.70	112.60	0.397	52.64	97.25	0.391	53.44	113.15	0.399
5.	58.33	108.15	0.388	58.07	113.70	0.379	54.37	92.95	0.394	54.87	111.35	0.396
Total mean average	56.26	106.42	0.3984	55.382	114.31	0.3944	55.01	97.09	0.3942	55.89	112.66	0.3948
	Check			Normal Nitrogen								
1.	74.84	87.15	0.343	69.95	102.70	0.384*	—	—	—	—	—	—
2.	73.97	69.30	0.341	68.52	121.55	0.401	—	—	—	—	—	—
3.	72.24	73.63	0.349	75.00	125.20	0.391	—	—	—	—	—	—
4.	73.12	76.95	0.363	73.88	122.70	0.396	—	—	—	—	—	—
5.	72.77	83.40	0.352*	73.35	120.45	0.394	—	—	—	—	—	—
Total mean average	73.388	78.086	0.3496	74.14	118.52	0.3932	—	—	—	—	—	—

*Indicates spurs from trees in their off year in bearing habit.

†Area = Cm^2.

‡Diameter = Cm.

TABLE IV—COMPARISON OF GROWTH MEASUREMENTS OF BALDWIN APPLES UNDER VARIOUS FERTILIZER TREATMENTS (ORCHARD J—1941) ALL SPURS NON-BLOOMING, SOD CULTURE

	Triple Nitrogen			Normal Nitrogen			Complete Fertilizer			Normal Nitrogen		
	Ratio	Area†	Diameter‡	Ratio	Area	Diameter	Ratio	Area	Diameter	Ratio	Area	Diameter
1	68.28	83.15	0.354	75.59	85.20	0.357	75.58	96.75	0.402	70.55	101.25	0.396
2	68.20	102.45	0.379*	76.97	131.45	0.414*	73.68	125.45	0.395	71.39	139.75	0.409*
3	66.97	90.45	0.357	72.57	110.25	0.388	70.22	116.95	0.382	75.26	107.05	0.404
4	68.79	93.50	0.365	69.53	117.80	0.395	72.91	120.30	0.386	76.75	121.35	0.405
5	69.24	95.65	0.369	71.82	113.15	0.393	75.42	121.35	0.371	68.92	119.85	0.402
Total mean average	68.296	93.04	0.3648	73.292	111.57	0.3894	73.574	116.16	0.3872	72.574	117.85	0.4032
	Normal N and P			Normal Nitrogen			Normal N and K			Normal Nitrogen		
1	73.41	115.95	0.425*	70.10	97.80	0.400	71.59	104.40	0.413*	72.39	105.55	0.397
2	71.87	118.90	0.387	72.52	138.45	0.409*	68.88	112.10	0.398	72.21	139.80	0.410*
3	71.50	122.95	0.393	71.45	118.95	0.400	68.26	110.00	0.402	71.77	113.90	0.390
4	69.64	119.65	0.415	71.58	116.85	0.394	68.60	111.50	0.407	73.60	129.85	0.394
5	73.36	116.70	0.400	70.29	116.12	0.405	72.60	111.75	0.400	69.13	110.35	0.392
Total mean average	71.956	118.83	0.404	71.168	117.63	0.4016	69.98	109.95	0.404	71.82	119.89	0.3966
	Check			Normal Nitrogen								
1	74.84	87.15	0.343	69.95	102.70	0.384*	—	—	—	—	—	—
2	73.97	69.30	0.341	68.52	121.55	0.401	—	—	—	—	—	—
3	72.24	73.63	0.349	75.00	125.20	0.391	—	—	—	—	—	—
4	73.12	76.95	0.363	73.88	122.70	0.396	—	—	—	—	—	—
5	72.77	83.40	0.352*	73.35	120.45	0.394	—	—	—	—	—	—
Total mean average	73.388	78.086	0.3496	74.14	118.52	0.3932	—	—	—	—	—	—

*Indicates spurs from trees in their off year in bearing habit.
†Area = Cm².
‡Diameter = Cm.

The presence of flowers and the fruiting condition has a marked effect upon the subsequent year's growth. This retardation was consistent in all four plots. This presumably is due to the utilization of carbohydrates and amino-acid reserves in the reproductive function. This same effect has been previously pointed out by Harley (2) who found that the leaf area on the non-bearing spurs were about double that on spurs bearing blossoms. The conclusions from this experiment further substantiate his findings.

Leaf ratios, it appears, do give some indication of growth condition of certain varieties. This seems to be particularly true in Delicious apples. From this study there does not appear to be any valuable application for either Baldwin or Stayman Winesap apples. Therefore, an arbitrary ratio would be of little value as a criterion for expressing growth status within these two varieties. The leaf ratios for Delicious did not, however, always hold constant. The Delicious trees in low relative vigor in the Melrose Orchards under a bluegrass sod culture had leaf ratios of nearly 60 per cent. This is out of line with previous findings, for trees under such conditions would be expected to have ratios of less than 50 per cent. Reasoning from this condition, it might be well not to make broad generalizations in regard to definite ratio values for some inconsistencies exist under specific conditions.

Variations in fertilizer treatment responses are clearly shown in Tables III and IV. The trees receiving the triple nitrogen in Orchard J have always been dense, with dark green leaves. Although the leaf area per spur was much smaller, the total number of spurs per unit area was greater. The trees in the check plots have the smallest leaf area per spur and the leaves are a light yellowish green and the growth of the trees is very open. Likewise the data show that the trees receiving normal nitrogen had the greatest leaf area and spur diameter. Thus it might be concluded that the leaf area and relative spur diameters are convenient and reliable criteria for measuring the vigor of trees under different cultural practices and in interpreting experimental results. Other factors, such as thickness of leaf and the amount of branching, are also important characters of growth.

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Maturity of Apple Fruits in Relation to the Rate of Transpiration[1]

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IT IS the opinion of cold storage operators and research workers alike that fruit harvested green and immature wilts much more than fruit that is fully colored and mature at the time of harvest (1, 2). This opinion is based on general observation rather than experimental data. Experimental data in support of this opinion have not been found in pomological literature.

Magness (4) measured the rate of transpiration of several apple varieties harvested at intervals from September 14 to October 10 and found no significant differences. Hinton (3) seemed to find that in some instances the late-picked apples transpired at a higher rate than earlier harvested fruits. He also called attention to the fact that the rate of transpiration of stored fruit decreased at first and then increased consistently. His results, however, are open to criticism, since neither humidity nor temperature were controlled in his experiment.

MATERIAL AND METHODS

Experiment I was conducted during the year 1941 in the laboratories of the Pomology Department[2] at Cornell University, Ithaca, New York, the fruit being picked in the University experimental orchards. Experiments II and III were carried on during the year 1942 at the Rhode Island Agricultural Experiment Station and the Merchants Cold Storage and Warehouse Company, Inc. in Providence, Rhode Island. The fruit for these two experiments was harvested in the College orchards, except for the Golden Delicious variety which came from Edwin Knight's orchards, Greenville, Rhode Island.

The rate of transpiration was measured by weighing individual fruits on a torsion balance whose sensitivity approached ten milligrams. The loss in weight was assumed to be due to transpiration only. No correction for the loss in weight as due to the loss of carbon in respiration was applied, since at the temperatures and humidities used the above said correction would not change the general trend of the data obtained appreciably.

The rate of transpiration was expressed in milligrams of water lost per kilogram of fruit whenever the apples to be compared were of uniform size and shape. When they differed, the results were expressed in milligrams of water lost per hundred square millimeters of surface area. The surface area was found by peeling the fruits, tracing the peelings on paper and measuring with a planimeter.

The study reported herein consisted of comparing the rates of transpiration of fruit at different stages of maturity. In Experiment I the fruit was picked every week throughout the entire growing season and the rate of water loss measured directly after harvest. This study had to be carried on at constant temperature and humidity in order that the rates of transpiration be comparable.

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[1] Contribution No. 636 of the Station.

[2] These data were used as a part of the author's Ph.D. thesis, "A Study of Factors Influencing the Rate of Transpiration of Apple Fruits".

In Experiment II the comparison was made between well-colored mature fruits on the one hand, and green immature fruits on the other, picked from different locations on the tree on the same day. The rate of transpiration of these two lots was measured directly after harvest at room temperature. There was no need of maintaining constant temperature and humidity, since the lots to be compared were subjected to the same changes of environmental conditions.

In Experiment III the fruits were harvested at 2-week intervals for some time before and after the commercial picking date. They were stored in the cold storage room at Providence. When all pickings were in, some fruits from each picking were taken to the laboratory and the rate of water loss determined. Other fruits were left in the cold storage and their rates of transpiration were compared therein. Since the transpiration of all lots to be compared was measured at the same time and under the same environmental conditions, there was again no need for maintaining constant temperature or humidity.

EXPERIMENT I

Four varieties of apples, Yellow Transparent — an early summer variety; McIntosh — a mid-fall variety; Golden Delicious and Baldwin — both late varieties, were chosen for this study. Directly after harvest they were brought to the constant temperature room maintained at 77 degrees F with fluctuations not exceeding 1 degree F. They were held there for 12 hours. After that time they were assumed to be in equilibrium with room temperature and were placed in tightly sealed 4.5 liter jars over a sulphuric acid solution that was calculated to give a constant relative humidity of 63 per cent (5).

At the beginning of the season 14 fruits of each variety divided equally between the two jars were used for each determination. As the season progressed and the fruits grew larger, the number was gradually decreased to four of each variety, two in a jar.

The results obtained are given in Tables I, II, III, and IV.

EXPERIMENT II

Four varieties were used for this study: USDA Seedling, Yellow Transparent, Duchess and Wealthy. The early varieties were chosen since their ripening is fast and rather wide differences in maturity between individual fruits can be found on the tree about harvest time.

The fruits were brought to the laboratory and their rate of transpiration determined for two consecutive days. The results obtained are given in Table V.

EXPERIMENT III

Four apple varieties — Baldwin, Golden Delicious, McIntosh and Rhode Island Greening were chosen for this experiment. Forty fruits of each variety were harvested every 2 weeks for some time before and after commercial harvest time and stored in a cold room. When all fruits were in, 10 apples from each picking were taken to the laboratory and the rate of water loss of all lots determined. The results are given in Table VI.

The remaining fruits were kept at the temperature of 31 to 32 degrees F and relative humidity close to 85 per cent. Continuous records of both temperature and humidity were kept by means of a hygrothermograph. The loss of water was determined for the period from November 3 to December 29, 1942, and the results obtained are given in Table VII.

DISCUSSION

As is seen from the results of Experiment I (Tables I to IV) the rate of transpiration of apple fruits decreases rapidly early in the season, slowly in mid-summer, and finally reaches its minimum shortly before picking time. Later on when the fruits passed the stage of picking maturity, the rate of transpiration seemed to increase somewhat. The increase was slight since the experiment ended before the fruits became

TABLE I—TRANSPIRATION RATE OF BALDWIN APPLES AT 77 DEGREES F AND 63 PER CENT RELATIVE HUMIDITY

Picking Date (1941)	Number of Fruits	Total Initial Weight (Grams)	Total Surface Area (Centimeters ^{2})	Transpiration Rate (Mg/100 Cm ^{2}/Hr)	Relative Transpiration Rate
Jun 20	14	224.45	555.5	17.17	178
Jun 27	14	302.18	662.0	15.54	162
Jul 4	12	346.67	602.4	15.94	166
Jul 11	12	448.21	673.0	14.23	148
Jul 18	10	576.73	735.5	14.62	152
Jul 25	8	600.19	712.2	13.90	144
Aug 1	8	614.14	710.0	14.87	155
Aug 8	8	680.02	757.5	12.54	130
Aug 22	6	660.50	705.7	11.80	123
Aug 29	6	695.60	734.0	11.61	121
Sep 5	4	493.30	508.6	10.17	106
Sep 12	4	499.14	545.0	9.62	100
Sep 19	4	583.02	615.0	10.60	110
Sep 26	4	577.21	632.0	12.10	126
Oct 3	4	566.69	613.0	11.17	116
Oct 10	4	626.14	673.0	12.40	129

TABLE II—TRANSPIRATION RATE OF GOLDEN DELICIOUS APPLES AT 77 DEGREES F AND 63 PER CENT RELATIVE HUMIDITY

Picking Date (1941)	Number of Fruits	Total Initial Weight (Grams)	Total Surface Area (Centimeters ^{2})	Transpiration Rate (Mg/100 Cm ^{2}/Hr)	Relative Transpiration Rate
Jun 20	14	108.28	283.3	42.36	368
Jun 27	14	181.52	387.5	31.48	274
Jul 4	10	175.12	344.0	31.10	271
Jul 11	10	282.70	505.0	25.94	226
Jul 18	10	351.36	581.2	22.37	195
Jul 25	10	437.52	673.6	21.38	186
Aug 1	8	485.70	710.2	20.84	181
Aug 8	8	517.77	722.0	17.31	151
Aug 22	6	550.28	740.0	14.05	122
Aug 29	6	570.07	757.1	13.47	109
Sep 5	6	631.76	770.0	12.84	108
Sep 12	6	665.50	775.2	12.58	110
Sep 19	4	487.09	534.0	11.47	100
Sep 26	4	504.56	527.6	12.21	107
Oct 3	4	574.42	635.4	12.20	106
Oct 10	4	559.44	630.8	12.49	109

TABLE III—TRANSPIRATION RATE OF McINTOSH APPLES AT 77 DEGREES F AND 63 PER CENT RELATIVE HUMIDITY

Picking Date (1941)	Number of Fruits	Total Initial Weight (Grams)	Total Surface Area (Centimeters ^{2})	Transpiration Rate (Mg/100 Cm ^{2}/Hr)	Relative Transpiration Rate
Jun 20	14	130.26	288.5	30.47	404
Jun 27	14	178.04	370.2	27.01	358
Jul 4	12	202.76	377.6	19.25	255
Jul 11	12	387.01	647.0	16.35	216
Jul 18	10	430.90	598.0	16.37	216
Jul 25	10	496.68	709.0	13.99	185
Aug 1	10	598.30	904.0	10.72	142
Aug 8	8	592.95	750.0	10.77	142
Aug 22	8	689.40	788.0	9.81	130
Aug 29	6	670.13	742.0	9.54	126
Sep 5	6	685.92	744.0	8.79	116
Sep 12	4	488.14	575.5	7.56	100
Sep 19	4	544.23	614.2	7.90	104
Sep 26	4	569.52	637.0	8.57	113
Oct 3	4	576.94	642.0	8.05	106
Oct 10	4	632.30	681.0	9.79	129

overmature. Yellow Transparent was the only exception, showing a marked increase in transpiration in the final stage. Here the fruits used at the end of the experiment were overmature.

It was fully realized that the methods employed in this experiment were far from perfect. The jars were rather small, tall, and narrow (4.5 inches in diameter, 12 inches in height). This would, however, not change the general trend of the data since the same source of error existed throughout the experiment.

TABLE IV—TRANSPIRATION RATE OF YELLOW TRANSPARENT APPLES AT 77 DEGREES F AND 63 PER CENT RELATIVE HUMIDITY

Picking Date (1941)	Number of Fruits	Total Initial Weight (Grams)	Total Surface Area (Centimeters ^{2})	Transpiration Rate (Mg/100 Cm ^{2}/Hr)	Relative Transpiration Rate
Jun 20	14	134.64	336.0	23.09	195
Jun 27	14	278.30	546.2	21.20	172
Jul 4	12	327.76	577.7	16.59	135
Jul 11	12	412.48	713.0	15.81	129
Jul 18	10	702.97	1060.0	13.21	108
Jul 25	8	680.70	876.5	14.07	115
Aug 1	8	615.84	849.0	12.27	100
Aug 8	8	619.39	764.0	13.42	109
Aug 22	6	636.40	780.0	15.81	129
Aug 29	6	635.79	784.0	17.00	138

Another possible source of error was the varying volume of fruits at the beginning of the experiment and later on. After midsummer it became almost constant for late varieties and did not complicate the results during the period of time in which we are most interested.

Although the samples were small, the significance of results is strengthened by the fact that four varieties were used for the same study and each variety was investigated at 77 degrees F and 32 degrees F. The results obtained at 32 degrees F are not given here since they represent exactly the same trend as those obtained at 77 degrees F, with the exception that the rate of transpiration was correspondingly lower.

A certain increase in the transpiration rate of apples at the end of the season as found in Experiment I during 1941 studies was unexpected and contrary to the generally accepted opinion. To secure further data on the subject, Experiments II and III were conducted during the 1942 season.

It is known that not all fruits ripen at the same time on the tree. The differences usually are most pronounced in the case of early varieties and these were chosen for the study (Table V). It was possible to find overmature fruits and some still green at the same time on Yellow Transparent and United States Department of Agriculture Seedling varieties. It was shown in both cases that overmature apples transpire at a much higher rate than do the green ones. The differences were smaller with Duchess and Wealthy varieties, but here the differences in maturity of the comparable samples as shown by the pressure test also were small.

TABLE V—TRANSPIRATION RATE OF GREEN IMMATURE FRUITS COMPARED WITH THAT OF WELL-COLORED MATURE FRUITS AT ROOM TEMPERATURE

Harvest Date (1942)	Maturity		Number of Fruits	Total Weight of Fruits (Grams)	Transpiration Rate (Mg/Kg/Hr)	Relative Transpiration Rate
	Color	Average Pressure Test (Lbs)				
			U. S. D. A. Seedling			
Jul 22	Green	6.7	20	1,543	210.2	100
Jul 22	Well-colored	2.3	20	1,650	308.8	147
			Yellow Transparent			
Jul 31	Green	7.2	20	2,327	147.4	100
Jul 31	Well-colored	Below 3.0	20	2,331	182.3	124
			Duchess			
Aug 28	Green	8.3	20	2,998	154.3	100
Aug 28	Well-colored	6.7	20	2,995	162.1	105
			Wealthy			
Aug 30	Green	11.3	20	3,295	135.0	100
Aug 30	Well-colored	10.0	20	3,295	140.1	104

With late varieties of apples it is difficult to find great differences in maturity on the same trees during the harvest time. Experiment III, therefore, was planned in a different way. Fruits picked at 2-week intervals from September 5 to October 29 were stored in a cold storage kept close to 32 degrees F and 85 per cent relative humidity. When all fruit lots were in, their rate of transpiration was compared at high and low temperatures.

Table VI shows clearly that all apple varieties behaved in the same way. The more mature the apples are, the faster they transpire when taken from cold storage to the room temperature.

Objection may be raised that the early picked lots were in storage for a longer time and the permeability of their skin decreased considerably because of desiccation or closure of lenticels. This is hardly the case, since after the apples were taken out of storage, they were kept for 2 weeks at room temperature and lost more than 5 per cent by weight, while the ratio of the transpiration rates of different lots remained practically constant. Table VI gives the average transpi-

TABLE VI—INFLUENCE OF MATURITY ON THE RATE OF TRANSPIRATION OF APPLES HELD AT ROOM TEMPERATURE

Picking Date (1942)	Initial Weight (Grams)	Number of Fruits	Transpiration Rate (Mg/100 Cm ^{2}/Hr)	Relative Transpiration Rate
		Baldwin		
Sep 19	1747.6	10	19.1	100
Oct 3	1824.0	10	27.0	141
Oct 17*	1611.4	10	25.1	131
Oct 29	1685.9	10	28.2	148
		Golden Delicious		
Sep 5	1228.1	10	31.2	100
Sep 19	1323.0	10	34.7	111
Oct 3*	1416.8	10	36.7	118
Oct 17	1433.5	10	45.0	144
		McIntosh		
Sep 5	1444.5	10	13.4	100
Sep 19*	1552.6	10	13.8	106
Oct 3	1515.6	10	19.2	143
Oct 17	1462.7	10	26.3	196
		R. I. Greening		
Sep 5	1662.5	10	14.3	100
Sep 19*	1735.5	10	17.0	119
Oct 3	1862.3	10	20.0	140
Oct 17	1795.7	10	20.0	140
Oct 29	1589.0	10	25.3	177

*Nearest to commercial picking date.

ration value for the 2 days after the test was started. It was thought unnecessary to give the data obtained on the subsequent days.

Table VII gives the rate of transpiration of different pickings while in cold storage. It was shown here again that the rate of transpiration

TABLE VII—INFLUENCE OF MATURITY ON THE RATE OF TRANSPIRATION OF APPLES HELD AT 32 DEGREES AND 85 PER CENT HUMIDITY

Picking Date (1942)	Weight on November 3 (Grams)	Number of Fruits	Transpiration Rate (Mg/Kg/Day)	Relative Transpiration Rate
		Baldwin		
Sep 19	5320.37	30	15.9	100
Oct 3	5538.57	30	23.0	145
Oct 17*	5329.88	30	23.1	145
Oct 29	5336.63	30	23.9	150
		Golden Delicious		
Sep 5	4062.50	30	36.2	100
Sep 19	4597.30	30	37.0	102
Oct 3*	4775.88	30	36.6	101
Oct 17	8131.93	30	41.2	114
		McIntosh		
Sep 5	4378.59	30	17.7	118
Sep 19*	4925.85	30	15.0	100
Oct 3	5235.86	30	22.0	147
Oct 17	5194.68	30	22.8	152
		R. I. Greening		
Sep 5	5149.88	30	10.4	100
Sep 19*	5524.63	30	12.4	119
Oct 3	5495.07	30	16.0	154
Oct 17	5295.14	30	17.8	171
Oct 29	5567.78	30	17.7	170

*Nearest to commercial picking data.

of overmature fruits is higher than that of immature fruits, although the differences are not as great as they were at room temperature.

Popular belief that early harvested immature apples wilt first has probably originated in the following way. Inspection in mid-January of two lots of apples, one picked on September 15, the other on October 15, will show almost invariably that the former has shriveled more than the latter. Attention, however, is called to the fact that the early picked apples have been kept in storage for 4 months (September 15 to January 15) as compared with 3 months (October 15 to January 15) for the apples picked later in the season. Assuming that green apples transpire at the same or even slightly lower rate than the mature fruits, we can easily understand why the former may have shriveled more.

In almost any storage the conditions for high transpiration rates exist early in the fall when the first lots of apples are being taken in from the orchard. These fruits are warm and make it very difficult to maintain a low temperature. The same effect is brought about by the frequent opening of the door of the storage room. The humidity also tends to be low during the first few weeks. The early harvested fruits are thus at a disadvantage. They are not only kept in storage for some additional length of time, but this period is especially trying for them.

Conclusions

The rate of transpiration of apple fruits tends to be very high early in the season. The skin of the fruit is very permeable to water vapor at that time of year, but its permeability decreases very rapidly and so does the rate of transpiration when measured at constant temperature and humidity. The permeability of the skin and the rate of transpiration reach their minimum shortly before the picking maturity is attained.

When picking maturity is passed, the apples transpire at a higher rate, especially when they are allowed to become overmature.

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The Comparative Value of Certain Plastic Materials and Waxes in Checking Moisture Loss from Apples

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MOISTURE loss from apples in storage constitutes a considerable problem with some varieties. Severe shriveling of varieties like Golden Delicious and Grimes Golden makes the fruit less attractive, reduces eating quality, and results in "slack" packages when the apples have been packed prior to storage.

Various treatments, such as wrapping and waxing (1, 2, 4, 5, 6, 7, 8, 9, and 12) have been tested as to their merit in reducing moisture loss but little has been done to evaluate the comparative values of these treatments. This study was conducted to determine the comparative merit of waxing, the use of latex coverings, wrapping with different types of Pliofilm, Cellophane, and aluminum foil. In one phase of the study, some of these treatments were used at three different relative humidities.

METHODS

Uniform Golden Delicious apples were used in each experiment. During the 1941 season the apples were held in ordinary cold storage for a short period before treatments were made but in the 1942 season treatments were made immediately after harvest.

With one exception noted in the text, the apples were picked at a stage of maturity judged to be prime for the best keeping in storage of this variety. Examination of the fruit for carbon dioxide content, quality, and degree of ripeness was made immediately upon removal from storage.

Where the fruit is designated as "wrapped", the wrappers were merely placed around the fruits and the edges twisted together. The Pliofilm bags were heat sealed and other "sealed" Pliofilm treatments were made by heat sealing the edges of the wraps. In some cases the "sealed" Pliofilm treatments were made following a heat treatment of the Pliofilm and then stretching this around the fruit. This made the thickness of the wrap thinner than it initially was.

All treatments were stored at 45 degrees F. In 1941 a low relative humidity (about 60 per cent) was used and in 1942 three different relative humidities were used.

Carbon dioxide in the internal atmosphere of the fruits was measured by Claypool's (3) method. A standard color chart was used to measure ground color differences, a Magness-Taylor pressure tester to measure changes in firmness and a portable refractometer to measure differences in soluble solids.

RESULTS

Latex Versus Wax Emulsion:—In 1941 a comparison was made between different dilutions of a latex emulsion prepared by the Firestone Company and Brytene wax emulsion 489AR. Both were diluted with water. Fig. 1 shows the weight losses occurring in Golden Delicious apples treated with different dilutions of these materials. Because of the stickiness of the latex material it was necessary to hang the fruits by the stems to dry after dipping in the emulsion.

Weight losses are closely correlated to the rate of dilution of both of these materials. When diluted with the same amount of water, the wax emulsion seemed slightly more efficacious than the latex. It should be noted, however, that a latex emulsion with a greater initial concentration of pure latex could undoubtedly be prepared. The treatment labeled "pure latex" meant merely that it was an undiluted form of the manufacturer's product.

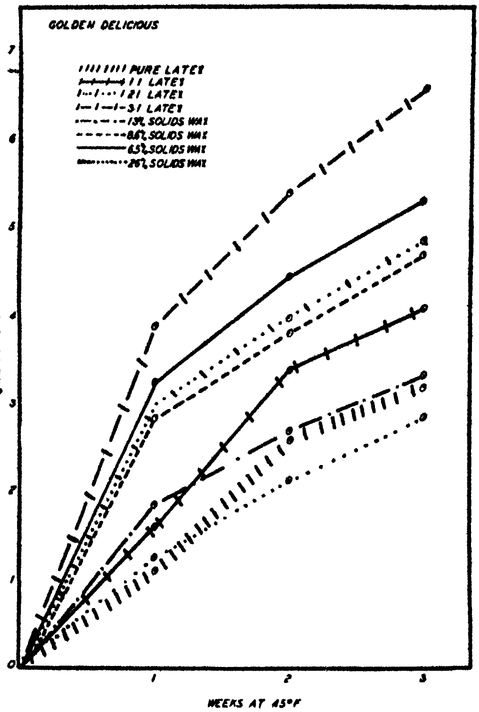

FIG. 1. Weight losses in Golden Delicious as affected by Latex dilutions and dilutions of wax (Brytene 489 AR).

Pliofilm Versus Aluminum Foil:—Several different thicknesses of Pliofilm were compared with aluminum foil in this experiment at a low relative humidity (60 per cent). All of the Pliofilm wraps were heat stretched around the fruit and then heat sealed. Fig. 2 indicates that Pliofilm N 140 F reduced weight loss the most followed in order by 107–N–1, 120 N–1, and 100 N–1. The total weight loss with all of these treatments was relatively small. Weight loss with the aluminum foil was slightly greater than with the Pliofilm treatments. The aluminum foil treatment gave the best eating quality fruit, however. The control had lost about four times as much in weight as the aluminum foil treatment after 5 weeks at 45 degrees F. The control fruits were unmarketable because of excessive shriveling.

Comparison of Different Wax Emulsions:—Four Brytene wax emulsions were compared in this experiment. All were diluted until they had 6 per cent solids each. Golden Delicious apples after being waxed with these four waxes were stored for 5 weeks at 45 degrees with a low (60 per cent) relative humidity. Table I gives the weight losses incurred with these different wax emulsions. Wax 489A seems slightly better from the standpoint of reducing weight loss than the others although it is only slightly better than RG 19. None of the

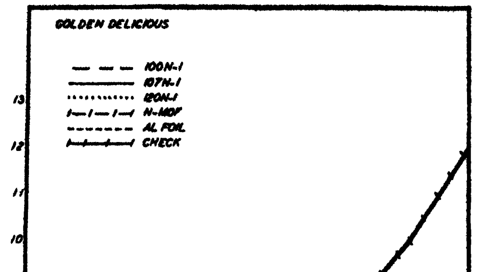

FIG. 2. Weight losses in Golden Delicious as affected by different types of Pliofilm wraps and aluminum foil.

differences are very large. The control was unmarketable because of excessive shriveling.

Comparison of Pliofilm, Cellophane and Latex:—In this experiment, in 1942, Golden Delicious apples were picked about 3 weeks before they were prime for harvest. They were treated and stored at 45 degrees F with a relative humidity of about 75 per cent. Pliofilm 120 N 2 was heat-stretched around the fruit and then the edges heat sealed. The Pliofilm bags were also heat sealed. All the other wraps were merely placed around the fruit and the edges twisted by hand. The latex designated by the Firestone Company as R 38789, was diluted with 33 per cent ammonium hydroxide. The Cellophane was designated as 450 LAT and the wax was Brytene 489 A.

The results are given in Fig. 3. It may be seen that the Pliofilm bags and the heat sealed 120 N 2 Pliofilm wraps were the most effective in reducing weight loss. These were followed in order by Pliofilm 100 N wraps, latex 1 : 2 (that is, diluted with two parts of 33 per cent ammonium hydroxide), cellophane 450 LAT, latex 1 : 3, wax (6 per cent solids) and the control.

The wax emulsion checked only about 20 per cent of the weight loss that occurred in the control. Cellophane and latex 1 : 2 checked about 50 per cent of the weight loss each.

TABLE I—WEIGHT LOSS IN GOLDEN DELICIOUS APPLES AS AFFECTED BY SEVERAL WAXES IN LOW HUMIDITY AT 45 DEGREES F

Treatment	Per Cent of Solids	Weight Lost After Weeks (Per Cent)				
		1	2	3	4	5
Control	–	0.94	2.07	3.77	5.65	7.54
Wax 489A	6	0.84	1.90	3.89	4.26	5.54
Wax 943E	6	0.89	1.89	3.09	4.99	6.48
Wax 943D	6	0.86	1.80	2.90	4.56	6.19
Wax R. G. 19	6	0.70	1.67	2.88	3.77	5.76

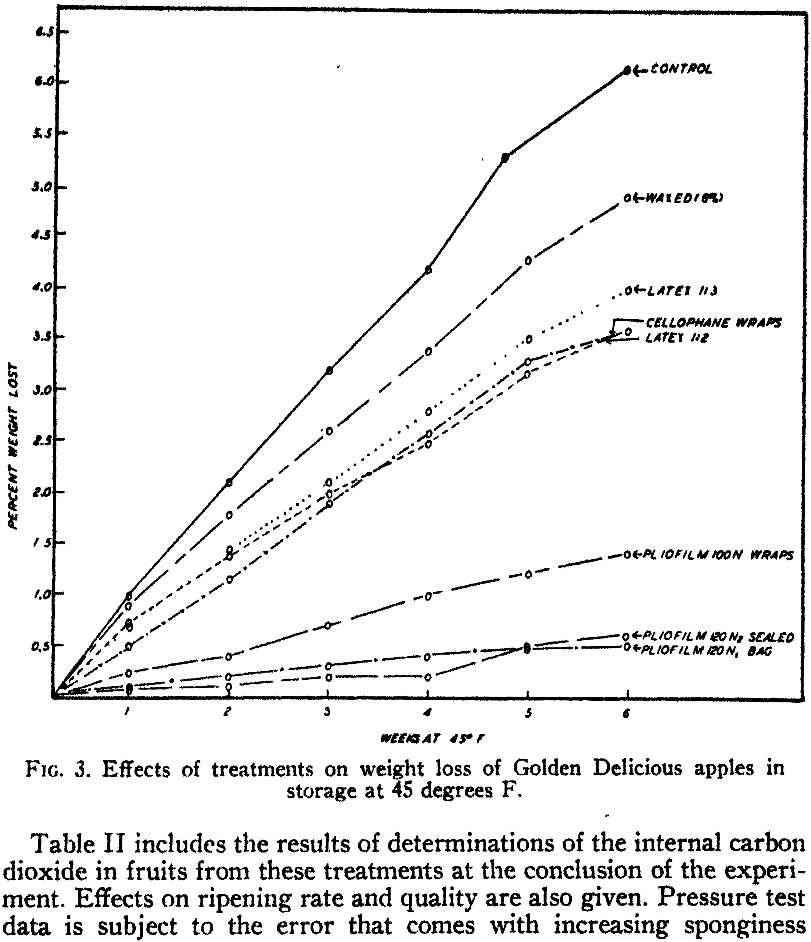

FIG. 3. Effects of treatments on weight loss of Golden Delicious apples in storage at 45 degrees F.

Table II includes the results of determinations of the internal carbon dioxide in fruits from these treatments at the conclusion of the experiment. Effects on ripening rate and quality are also given. Pressure test data is subject to the error that comes with increasing sponginess of the fruit as it loses water.

Table II indicates that the control had the least internal carbon dioxide. The Pliofilm bags and sealed wraps which resulted in the

TABLE II—EFFECT OF VARIOUS WRAPS, LATEX, AND WAX ON WEIGHT LOSSES FROM GOLDEN DELICIOUS AFTER SIX WEEKS AT 45 DEGREES F

Treatment	Total Weight Lost (Per Cent)	Mg of CO_2 Per Kilogram Fruit	Ground Color	Firmness (Lbs)	Soluble Solids (Per Cent)	Remarks
Control	6.20	57.5	4.0	10.0	12.4	Unmarketable
Latex 1:2	3.61	79.0	3.2	14.0	13.1	Good condition
Latex 1:3	4.00	66.4	3.0	13.0	12.1	Good condition
Waxed 6 per cent solids	4.92	64.5	3.6	12.0	13.2	Unmarketable
Sealed Pliofilm 120 N 2	0.59	105.0	2.9	14.7	13.1	Good condition
Pliofilm 100 N wraps	1.24	93.0	3.6	11.0	13.2	Fair condition
Pliofilm 120 N-1 bags	0.52	113.0	2.6	15.0	12.1	Inedible
Cellophane	3.62	86.0	3.6	12.0	13.7	Some shriveling

least weight loss resulted in the greatest accumulation of carbon dioxide within the tissues of the fruit. There is an inverse relation between weight loss and accumulations of carbon dioxide in all cases. The wax emulsion, unsealed Pliofilm 100 N, and cellophane seemed to have the least effect of any of the treatments in retarding ripening. The remaining treatments were somewhat more effective in retarding ripening.

Carbon dioxide accumulations within the Pliofilm bags were so great that the bags were actually inflated because of the positive pressure within them. Fruits in these bags were inedible because of off-flavors. Fruits were in their best condition in the stretched and sealed Pliofilm 120 N 2 treatment. Why this should be so when the accumulated carbon dioxide was only slightly less in this treatment than in the Pliofilm bags is not known.

Comparison of Different Treatments Under Three Relative Humidities:—During the 1942 season, Golden Delicious apples picked at what was judged to be their best date of harvest were used for this experiment. After being treated in various ways, they were stored at 45 degrees F in low (60 per cent) medium (75 per cent), and high (90 per cent) relative humidities. In this experiment, none of the Pliofilm treatments were heat stretched even though some were sealed.

Table III includes the results obtained with the different treatments in the three relative humidities. The use of a high relative humidity (that is control in high humidity) was not as efficacious in reducing moisture loss as some of the treatments made in the low humidities. The use of a relative humidity close to the saturation point should

TABLE III—EFFECT OF VARIOUS TREATMENTS TO PREVENT MOISTURE LOSS ON GOLDEN DELICIOUS AT THREE HUMIDITIES AT 45 DEGREES F

Treatments	Per Cent of Weight Loss Each Week				
	1	2	3	4	5
		High Humidity			
Control	0.80	1.95	3.40	4.18	5.00
Latex 1:1	0.60	1.16	1.63	2.16	2.58
Sealed Pliofilm 120 N-2	0.06	0.06	0.24	0.67	0.67
Unsealed Pliofilm 100-N	0.20	0.69	0.69	1.00	1.27
Sealed Pliofilm 100-N	0.22	0.22	0.55	0.55	0.93
Cellophane	0.16	1.08	1.61	2.26	2.47
		Medium Humidity			
Control	1.63	2.91	4.43	5.82	7.05
Latex 1:1	0.42	0.96	1.70	2.35	2.93
Latex 1:2	0.74	1.27	2.11	2.74	3.38
Latex 1:3	0.89	1.48	2.43	3.14	3.85
Waxed 6 per cent	0.66	1.24	2.10	2.74	3.25
Sealed Pliofilm 120 N-2	0.11	0.114	0.343	0.455	0.52
Unsealed Pliofilm 100 N	0.22	0.465	0.93	1.28	1.62
Sealed Pliofilm 100 N	0.12	0.308	0.492	0.924	1.17
Cellophane	0.70	1.18	1.88	2.44	2.95
		Low Humidity			
Control	2.04	3.93	6.25	7.92	9.9
Latex 1:1	0.94	1.63	2.68	3.45	4.23
Sealed Pliofilm 120 N-2	0.06	0.123	0.43	0.615	0.80
Unsealed Pliofilm 100 N	0.23	0.53	1.23	1.70	2.29
Sealed Pliofilm 100 N	0.37	0.64	1.13	1.50	1.98
Cellophane	0.81	1.47	2.55	3.20	4.06

prove just as good as these wrapping treatments, however. If the weight loss which occurred in the controls is taken as 100 per cent the following reduction in weight losses were accomplished by the various treatments:

1. After 5 weeks with a high relative humidity the sealed 120 N–2, the sealed 100 N, and unsealed 100 N Pliofilm reduced the weight losses by 87, 81, and 75 per cents respectively. Under a medium relative humidity they (in the same order) reduced weight losses by 93, 83, and 77 per cents respectively. Under a low relative humidity they reduced the weight losses by 92, 80, and 77 per cents respectively. It may be seen here that the *relative* effectiveness of these three treatments remained about the same at three different humidities.

2. The latex 1 : 1 reduced the moisture loss by 49 per cent under high relative humidity, 58 per cent under medium humidity and 57 per cent under low humidity.

3. The cellophane reduced the moisture loss by 51 per cent under high relative humidity, 58 per cent under medium humidity and 59 per cent under low humidity. It would seem that its *relative* merit was about the same at all three humidities.

4. Brytene 489 A at medium relative humidity reduced the weight loss by 54 per cent and latex 1 : 2 and 1 : 3 by 52 and 45 per cent respectively.

The results of these treatments on the internal carbon dioxide, rate

TABLE IV—EFFECT OF VARIOUS TREATMENTS ON GOLDEN DELICIOUS APPLES UNDER DIFFERENT HUMIDITIES AT 45 DEGREES F

Treatments	After Five Weeks at 45 Degrees F					
	Total Weight Lost (Per Cent)	Mg of Internal CO_2/ Kilo	Ground Color	Per Cent Soluble Solids	Firmness (Lbs)	Remarks
Low Humidity						
Control	9.9	31.0	4.0	11.0	15.1	Unmarketable, spongy
Latex 1:1	4.23	119.0	3.6	12.6	14.0	Fair condition, mealy
Sealed Pliofilm 120 N-2	0.80	137.0	3.7	10.6	13.1	Good condition, mealy
Unsealed Pliofilm 100 N	2.29	94.0	4.0	9.8	14.1	Good condition, mealy
Sealed Pliofilm 100 N	1.98	113.0	3.9	10.0	12.9	Good condition, mealy
Cellophane	4.07	89.0	3.8	11.0	13.9	Fair condition, mealy
Medium Humidity						
Control	7.05	31.3	4.0	12.0	14.7	Unmarketable, spongy
Latex 1:1	2.93	58.5	3.6	14.0	15.2	Good condition
Latex 1:2	3.38	37.6	3.8	11.5	14.6	Good condition
Latex 1:3	3.85	33.4	3.9	10.8	14.6	Good condition
Waxed 6 per cent solids	3.25	29.8	3.8	11.0	14.3	Good condition
Sealed Pliofilm 120 N 2	0.51	85.8	3.6	11.0	13.1	Slightly off flavor
Unsealed Pliofilm 100 N	1.62	62.2	4.0	11.5	14.7	Good condition, slightly mealy
Sealed Pliofilm 100 N	1.17	87.0	3.6	11.5	14.1	Good condition, good flavor
Cellophane	2.95	61.3	3.9	11.5	14.9	Good condition
High Humidity						
Control	5.00	29.6	4.0	11.0	13.7	Fair condition
Latex 1:1	2.58	59.0	3.6	12.3	15.8	Good condition
Sealed Pliofilm 120 N 2	0.67	82.3	4.0	11.5	12.7	Mealy, good flavor
Unsealed Pliofilm 100 N	1.27	32.1	4.0	12.8	14.3	Mealy, good flavor
Sealed Pliofilm 100 N	0.93	57.5	4.0	11.0	14.1	Good condition
Cellophane	2.47	32.6	3.8	11.0	13.8	Good condition

of ripening and quality at three relative humidities are given in Table IV. There was a more or less positive correlation between the amounts of accumulated carbon dioxide and the ability of a treatment to check moisture loss. With one exception (latex 1 : 1) the Pliofilm treatments resulted in greater accumulations of carbon dioxide than the other treatments. The internal carbon dioxide accumulations seemed greater at a low relative humidity than they did at the medium. They were greater at a medium humidity than at the high.

In this experiment the latex 1 : 1 treatment had the greatest effect on reducing ground color changes on these fruits. The wax treatment had about the same effect on ground color as the cellophane. The latex 1 : 1 treatment had the greatest influence on reducing softening in the low and the high humidity chambers. Pliofilm treatments had little effect on the rate of softening.

There was a tendency toward mealiness in the Pliofilm treatments and a suggestion of some off flavor in some of the fruits. This was especially true in the sealed 120 N 2 Pliofilm lot. The best flavor was had in the fruits treated with wax, cellophane, and latex.

DISCUSSION

The wax emulsions (6 per cent solids) used in this experiment did not seem as effective in reducing moisture loss as the other treatments. Claypool (2) has shown that the types of waxes used in the emulsion greatly affect the moisture loss from fruits. In this study differences between different emulsions were apparent but the differences were not large. This study would seem to put the use of wax emulsions at a disadvantage in comparison with the other materials used but certain other considerations should be noted. The wax can be applied relatively easily. It can probably be used somewhat more cheaply than the other materials tested. There is no necessity of removing the covering of the fruit before it is consumed. Some of the wrapping treatments were made on other varieties in a preliminary study not reported on in this investigation. With some varieties the development of storage scald was greatly increased. Plagge and Maney (8) have also noted this. Waxing does not increase the development of scald except under certain circumstances (10) and some waxes (11) are as effective as oiled paper in controlling storage scald.

A comparison of a latex emulsion with wax emulsions showed some variation. These two materials were not compared on a basis of equal content of solids but on a basis of dilutions that might be used commercially. In general there was no great difference in the ability of the two to reduce moisture losses. It is more difficult to handle apples after they have been dipped in latex and they must be treated with something like talc to reduce their stickiness. The apples must be "peeled" free of the latex before they are consumed. No off flavors were noted when latex was used, although carbon dioxide accumulated in considerable quantities in some cases in latex treated fruit. Comin (4) reports good results with this material. Aluminum foil showed considerable merit in reducing moisture loss. No comparisons were made with wax but it is probably more effective than the more dilute emulsions of wax. It was less effective in reducing moisture loss than any of the types of Pliofilm that it was compared with.

Cellophane (450 LAT) was effective in lengthening the marketable period for Golden Delicious. It proved to be more or less comparable in its effect to latex diluted about 1:1 or 1:2. No off flavors were noted with cellophane. Phillips (7) has reported that apple varieties adapted to controlled atmosphere storage were adapted to the use of moisture proof cellophane in reducing weight loss. Baker (1) has reported good results with cellophane on Golden Delicious.

In general, Pliofilm was more effective than any other material tested in this study. The effect of Pliofilm depends upon its thickness and whether or not it is heat sealed. The original gauge of this material is considerably lessened when it is heat stretched. In this study it was shown that the heavier the gauge the less weight was lost by the fruit. While Pliofilm is supposed to be relatively permeable to carbon dioxide (12) considerable accumulations built up within heat sealed wraps. Occasional off flavors were encountered when this wrap in the heavier weights was used. Of course, the alcoholic flavors may have been due to relative impermeability to oxygen. In any case, greater accumulations of carbon dioxide occurred within the fruit with this treatment than with any other. Plagge and Maney (8) have reported that in Pliofilm lined apple boxes the concentration of carbon dioxide reached 10 per cent. It may be concluded that Pliofilm is very effective in reducing moisture loss from the apples used in this study but that care must be taken in selection of the proper weight of material so that off flavors may not result. With some of the Pliofilm treatments in this study, free water occurred inside the wrap and molds began to grow.

The use of a very high relative humidity will adequately check moisture losses from Golden Delicious apples in cold storage. Surface molds are very likely to grow under these circumstances. The fruit is not protected from shriveling upon removal to the market place, however. Greater accumulations of carbon dioxide were noted in fruit under low humidities in this study than under high when the various fruit treatments were made.

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The Influence of Maturity and Storage Temperature on the Ripening Behavior and Dessert Quality of the Italian Prune

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A LARGE portion of the Italian Prune crop grown in the Pacific Northwest is shipped as fresh fruit to markets in the east. Maturity of the fruit when harvested and its temperature during transit determine to a large degree the dessert quality of the prunes as they reach the ultimate consumer.

The need of a satisfactory index for judging maturity of Italian Prunes has long been recognized. In order to evaluate the usefulness of various possible indexes, preliminary studies were conducted during the 1941 season. This paper presents the results of these studies as well as some on ripening behavior and dessert quality as influenced by storage temperature in air and in carbon dioxide gas. It is planned to continue these studies under commercial handling and shipping conditions during the coming season.

Review of Literature

Considerable work has been published on different indexes for the determination of optimum maturity of prunes. Changes in skin and flesh color, in firmness, in soluble solids, and in acidity have all received attention. Hartman (2) found marked increases in sugar content and size, and decreases in firmness and acidity as maturity advanced. He concluded that firmness, as measured by the Oregon pressure tester using a ⅜ inch plunger, was the most reliable guide to maturity. Tucker and Verner (4) concluded that acid changes were too small and sugars were too variable with flavor to be reliable indexes of proper maturity. They recommended firmness of the fruit as the best guide to the harvesting of the fruit at optimum maturity. Using a pressure tester with a 5/16 inch plunger, they suggested that fruit for immediate shipment should have a range of firmness of 12 to 8.5 pounds. Fisher (1) after a three-year study, concluded that firmness was an unreliable guide to prune maturity, chiefly because of seasonal conditions and orchard differences. He found that soluble solids, as measured by a Zeiss refractometer, were closely related to dessert quality and recommended a minimum of 17 per cent for satisfactory dessert quality. Chastain and Nydren (5) after a three-year survey of commercial shipments, favored ground color changes and soluble solids (16 per cent minimum) as the most workable indexes of prune maturity.

The literature contains only a limited amount of information on the ripening and dessert quality of fruit of the Italian Prune as influenced by storage temperature. Ryall (3) reported that after 3 weeks of storage at 45 degrees F and subsequent ripening at 65 degrees the fruit showed characteristic browning about the pit. Hartman (2) obtained optimum dessert quality in prunes after 12 days' storage at 45 degrees and 3 to 4 days' ripening at 65 degrees. Fisher (1) stated that prunes with a soluble solids content of 18 per cent could be held at 32 degrees for a month and ripened satisfactorily in 5 to 7 days at 65 degrees. Tucker and Verner (4) recommended "limited periods" of storage at 32 to 35 degrees as practicable for Italian Prunes.

EXPERIMENTAL PROCEDURE

Fruit for the major portion of this study was obtained from an orchard at Cashmere, Washington. Pickings of 75 to 90 pounds of fruit were made at weekly intervals from September 1st to 22nd. In addition two lots of fruit of varying commercial maturity (as graded by the State Inspection force on the basis of color and size) were harvested August 24th in the Milton-Freewater district of Oregon.

Well composited 20-pound lots of fruit from each source and picking were stored immediately at 31, 36, and 45 degrees F in air, and at 45 degrees in 20 per cent CO_2 gas for 10 and 20 days prior to removal for ripening at 65 degrees.

Soluble solids in the juice from the ground pulp of 25 fruits were determined by a pocket-model Zeiss refractometer. Total acid in an aliquot of this juice was measured electrometrically and expressed as per cent malic acid. Firmness was determined by puncturing two sides of 15 unpeeled fruits with a Magness-Taylor type pressure tester using a 5/16 inch plunger. Increase in weight was found by weighing 50 representative fruits at each harvesting date.

RESULTS

Maturity Indexes at Harvest:—The data on the various physical and chemical characteristics of fruits of the Italian Prune at harvest are shown in Table I, but they should be evaluated in terms of the subsequent dessert quality of the ripened fruit as shown in the second

TABLE I—PHYSICAL AND CHEMICAL CHARACTERISTICS OF FRUITS OF THE ITALIAN PRUNE AS INFLUENCED BY MATURITY AT HARVEST

Date of Harvesting	Skin Color	Flesh Color	Pressure Test for Firmness (Pounds)	Total Acids (Per Cent)	pH	Soluble Solids (Per Cent)	Weight 50 Fruits (Gms)	Increase in Weight (Per cent)	Solids: Acid (Ratio)
			Cashmere Orchard						
Sep 1. . . .	Light purple slight green at suture	Light green to light amber	10.9	1.22	3.38	12.8	1,487	0.0	10.5
Sep 8.	Light to medium purple	Light to medium amber	10.2	1.22	3.50	15.2	1,611	8.3	12.4
Sep 15.	Medium to dark purple	Medium amber	7.4	1.10	3.62	16.0	1,730	7.3	14.5
Sep 22 . . .	Dark purple	Deep amber	7.0	1.01	3.75	17.4	1,868	7.9	17.2
			Freewater Orchard						
Aug 24 (immature)	Light to medium purple	Pale green to light amber	12.6	1.23	3.25	13.8	—	—	11.2
Aug 24 (mature)	Medium purple	Light to medium amber	12.1	1.14	3.33	13.8	—	—	12.1

section of this paper. Changes in skin and flesh color were directly associated with degree of maturity and aided in judging it. They were, however, of most value in this study when used in conjunction with measurements of soluble solids and the solids-acid ratio. Firmness, as shown in Table I, did not indicate differences in maturity to the extent of being a dependable index. Thus at the end of the first week there was a decrease in pressure test of only 0.7, followed by a 2.8 pound decrease by the second week and again only 0.4 for the third week at which time the fruit was practically tree ripe. Furthermore, while the mature fruit of the Freewater orchard and the second picking of the Cashmere orchard were judged to be of similar maturity on the basis of skin and flesh color and the solids-acid ratio, the difference in firmness amounted to approximately 2 pounds.

Soluble solids and especially the ratio of solids to acid appear to offer practical guides to prune maturity. On the basis of these indexes and the results of ripening studies after storage, fruit picked with a solids-acid ratio of 14.5 was the best for fresh fruit shipment. Soluble solids were somewhat lower in this fruit than the 17 per cent recommended by Fisher (3) for minimum maturity. The data in Table I and the results from subsequent storage and ripening studies show that acceptable maturity was obtained in fruit with a soluble solids range of 14 to 16 per cent.

Increase in weight of the fruit from the Cashmere orchard during a harvesting period of 3 weeks averaged 7.8 per cent per week, or slightly more than 1.1 per cent per day. This increase in tonnage of 1 per cent per day should discourage the tendency toward premature harvesting.

Storage and Ripening Studies:—Italian Prune fruits of four maturities from one orchard and two maturities from another were ripened at 65 degrees F and 80 per cent relative humidity after storage for 10 and 20 days at temperatures of 31, 36, and 45 degrees in air, and at the latter temperature in 20 per cent CO_2 gas. Decay and shriveling did not affect the marketability of the fruit of any maturity, even after storage at 45 degrees for 20 days. Ripening after storage was a very imporant factor in obtaining satisfactory dessert quality in fruit of early maturity. Thus the fruit from the second picking at Cashmere was scarcely edible when removed from 45 degrees after 10 days' storage, yet after ripening at 65 degrees it attained a juicy texture and a fair to good flavor. The data on the ripening and dessert quality of the 48 lots of fruit cannot be presented to the best advantage in tabular form. They are, however, summarized as follows:

First Picking, Cashmere Orchard:—(10 days' storage). At the time of withdrawal for ripening, the lot held at 45 degrees F was slightly darker in color than that held at 36 or 31 degrees. Pressure tests of firmness at this time were as follows: 45 degrees, 9 pounds; 36 degrees, 11.6 pounds; 31 degrees, 12.0 pounds; 45 degrees, in 20 per cent CO_2, 11.7 pounds. The fruit at this maturity, regardless of storage temperature, ripened with an astringent, acid flavor. The 45-degree lot ripened in 4 days with a juicy texture but poor flavor. The 36-degree lot ripened in 6 days and the 31-degree lot in 8 days. Both of the latter lots ripened with a mealy texture and general lack of juiciness. The lot held at 45 degrees in 20 per cent CO_2 gas failed to ripen normally and showed internal breakdown and discoloration of the flesh around the pit by the fifth day of ripening.

(20 days' storage.) At the time of removal from storage, the 45-degree lot was soft, darkest in color, and practically eating-ripe. The 31-degree lot was lightest in color and had softened but little since harvest. The 45-degree lot ripened normally in 3 days with good texture, and a flavor somewhat inferior to that held for only 10 days. Both the 36-degree and the 31-degree lots failed to ripen normally by the seventh day. They softened but were exceedingly mealy and showed breakdown of the tissue prior to attainment of satisfactory edibility.

Second Picking, Cashmere Orchard:—(10 days' storage). At the time of withdrawal for ripening, the darkest colored fruits were again found in those lots stored at the highest temperatures. Firmness at this time was as follows: 45 degrees, 7.8 pounds; 45 degrees in 20 per cent CO_2, 10.7 pounds; 36 degrees, 11.1 pounds; and 31 degrees, 11.9 pounds. The ripened fruit of this maturity was of considerably better flavor and dessert quality than the first picking. It lacked full varietal flavor, but was considered sufficiently mature to meet the minimum standards of dessert quality for fresh fruit shipment. The 45-degree storage lot ripened with a juicy texture and fair to good flavor in 4 days, becoming over-ripe but with no off flavor or tissue discoloration in 6 days. The lot gassed with CO_2 at the same temperature showed tissue breakdown and off flavor in 3 days of ripening at 65 degrees. The fruit stored at 36 and 31 degrees ripened in 6 and 7 days respectively, with a mealy texture and a less desirable dessert quality than that stored at 45 degrees.

(20 days' storage.) The 45-degree lot was eating-ripe, of juicy texture and fair dessert quality at the time of removal and remained so for 3 additional days at 65 degrees. The comparable lot held in 20 per cent CO_2 gas was inedible. The 36- and 31-degree lots softened slightly in 4 days and were mealy, too dry in texture, and flat in taste, the fruit held at 31 degrees being much the poorer lot.

Third Picking, Cashmere Orchard:—(10 days' storage). At the time of withdrawal for ripening, firmness of the various lots was as follows: 45 degrees, 6.3 pounds; 45 degrees in 20 per cent CO_2, 7.5 pounds; 36 degrees, 8 pounds; 31 degrees, 8 pounds. There were no observed differences in color of the various lots; all were full deep purple. The fruit at this maturity was considered optimum for fresh fruit shipment. It was noticeably softer than that from the second picking and slightly firmer than the fourth picking, and ripened with full flavor. The 45-degree lot ripened with a juicy texture and excellent dessert quality in 3 days, remained nearly prime for 5 days, but became mealy and over-ripe in 6 days. The gas-stored fruit again was inedible. The 36-degree lot became soft-ripe and mealy in 4 days, and was less flavorful than the 45-degree lot in air; after 6 days it showed tissue discoloration and breakdown. The 31-degree lot was poorer than that held at 36 degrees.

(20 days' storage.) The 45-degree lot was full ripe, juicy and of good dessert quality upon removal from storage; it remained so for 3 days at 65 degrees. The 36-degree fruit ripened in 3 days with a lack of juiciness and flavor, and after 5 days the tissue had become watersoaked with considerable breakdown. The 31-degree lot again was in worse condition than that held at 36 degrees.

Fourth Picking, Cashmere Orchard:—(10 days' storage). Fruit of this picking was almost tree-ripe at harvest and too mature for distant shipment. That held in air at 45 degrees was ripe and of good flavor upon removal from storage. It became mealy and over-ripe in 3 days at 65 degrees. The 36-degree lot was mealy in texture with poor dessert quality upon removal, and by the third day at 65 degrees showed watery breakdown of the tissue. The 31-degree lot was very mealy and abnormal in taste upon removal, and showed severe tissue discoloration and breakdown after ripening for 4 days. No attempt was made to store the 4th picking for more than 10 days.

Freewater Orchard:—(10 days' storage). The fruit of both maturities stored at 45 degrees was darker in color than that held at 36 degrees. Firmness of the more mature lot was as follows: 45 degrees, 9.2 pounds; 45 degrees in 20 per cent CO_2, 11.2 pounds; 36 degrees, 13.0 pounds. There were no marked differences in flavor or dessert quality of the ripened fruit of either maturity. In fact both lots were judged to be of similar maturity to the second picking of the Cashmere orchard and barely met minimum dessert quality requirements for fresh fruit shipment. The 45-degree lots of both maturities required from 3 to 4 days at 65 degrees to ripen with juicy texture and fair dessert quality. Comparable lots held in 20 per cent CO_2 ripened abnormally and showed tissue discoloration by the seventh day. Lots stored at 36 degrees ripened in 5 to 6 days with somewhat mealy texture and generally poorer flavor than those held at 45 degrees.

(20 days' storage.) Both maturities held at 45 degrees were almost eating-ripe upon removal. They were juicy in texture and of fair dessert quality after 2 days at 65 degrees. The CO_2 gassed lots, because of tissue discoloration and anaerobic flavor, were discarded after 2 days of ripening. Fruit of both maturities when held at 36 degrees for 20 days failed to soften and ripen normally. Most fruits showed internal browning and breakdown of the tissue before attaining eating quality.

SUMMARY

In this study, fruits of the Italian Prune showed an increase in fresh weight of approximately 1 per cent per day during a harvesting period of 3 weeks. On the basis of this year's work it appears that changes in color of the skin (with bloom removed) together with changes in soluble solids and especially the ratio of soluble solids to total acid are usable indexes of picking maturity for Italian Prunes. Acceptable shipping and dessert quality was shown by fruit harvested with soluble solids ranging between 14 and 16 per cent, and with a solids-acid ratio between 12 and 15. Optimum maturity for best dessert quality consistent with satisfactory condition to withstand simulated shipment to eastern markets was found in fruit from the Cashmere orchard on September 15 (third picking). This was approximately 1 week later than the regular commercial harvest.

Italian Prune fruits, regardless of maturity, failed to ripen normally with a juicy texture at 65 degrees F and 80 per cent relative humidity after storage for 10 days at a temperature of 31 or 36 degrees F. All samples of fruit ripened satisfactorily following storage at 45 degrees for 10 days, or ripened normally following storage at this temperature for 20 days. The fruit could not be stored at this temperature in 20 per cent CO_2 gas for 10 days, however, without breakdown of the tissue and the production of abnormal flavors upon ripening.

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A Note on the Measurement of Flesh Tenderness in Arizona Marsh Grapefruit

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TENDERNESS tests are used as a means of estimating maturity and palatability in many fruits and vegetables, notably pears and peas. The possibility that flesh tenderness of grapefruit could be correlated with juice measurements was suggested from grapefruit maturity studies conducted by the writer (1). Juice measurements are influenced by the thickness of the peel when percentage calculations are based upon the whole fruit. To correct these values by determining the amount of the peel requires too much additional labor to be of practical value to the Citrus Standardization Service. A simple method of estimating the juiciness of the edible portion would improve standards and be of economic value to the citrus industry.

Methods

To quickly ascertain the tenderness of the flesh, an instrument was devised similar to the well known pear pressure tester. This penetrometer was mounted in a vertical position in such a manner that it could be moved downward smoothly with a lever. Two brass rods, each .52 centimeters in diameter and 1 and ¾ inches apart, were used as a plunger. These were centered on two carpels of a cross sectioned grapefruit and forced into the flesh to the depth of 1 centimeter. The required force was measured with an open manometer, recorded in millimeters of mercury.

Weekly tests were made upon samples composed of 12 representative fruit from 12 Salt River Valley groves. After weighing, the fruit was cross sectioned and the tenderness of flesh of the stylar half of each fruit ascertained from two measurements by the pressure tester. These 24 measurements were averaged to obtain the tenderness of each sample. The juice was extracted on a power reamer, strained, and the juice squeezed from the juice-pulp mass remaining in the strainer. Its total volume and specific gravity were measured and weight calculated. After removing the membrane tissue, the peel was weighed. Juice percentages were calculated upon the basis of the weight of the edible portion which was ascertained by deducting the weight of the peel from the weight of the entire fruit.

Tenderness Tests

Preliminary tenderness tests showed that a rather wide range of pressure values existed between individual carpels of a single fruit. However, duplicate measurements on 100 fruits with the dual plunger revealed only an average standard error of the mean of .27 centimeters of mercury for each fruit. Greater differences occurred between the fruits in the sample. Thirty samples had an average standard error of the mean of .99 centimeters of mercury.

The seasonal changes in the tenderness of the flesh and the percentage of juice in the edible portion of Marsh grapefruit during the 1939–

1940 season are shown in Fig. 1. Weekly averages of the 12 samples tested are indicated for the pressure values (relative tenderness) and the percentage of juice. The curves for the seasonal trends of these averages were calculated from the formulae $y = a+bx+cx^2$. Pressure values for relative tenderness decreased from 26 centimeters in September to seven centimeters in January. During this period the percentage of juice in the edible portion increased from 58 to 78 per cent. Palatability improved and the fruit became edible during this interval. A comparison of these seasonal changes indicates that a close relationship is present between juiciness of the fruit and tenderness of the flesh. Since juiciness is related to palatability of the fruit it is evident that tenderness is also a measurement of palatability.

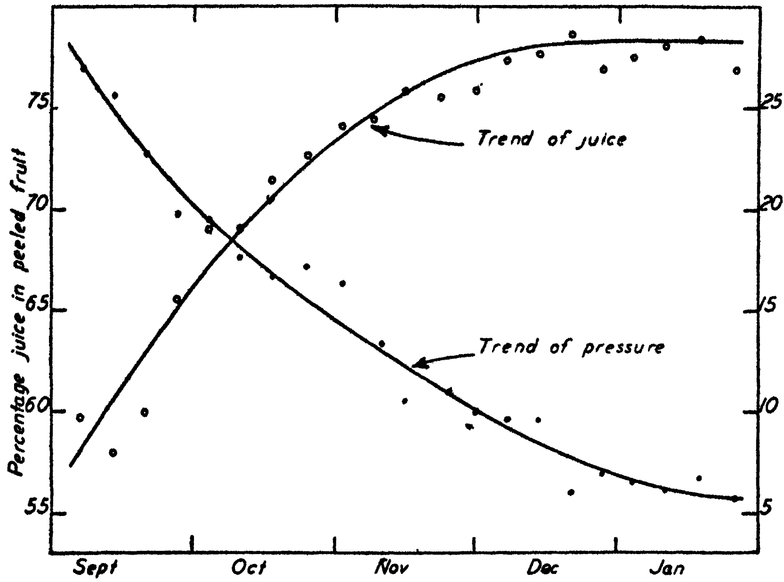

FIG. 1. Seasonal changes in the percentage of juice in the edible portion and the pressure values (tenderness) of Marsh Grapefruit.

To further investigate the relationship between juice and tenderness, 28 tests made between October 19 and 26 were studied. Using Pearson's method, the coefficient of correlation was found to be —.754 with a probable error of .0815. These values indicate that a definite inverse correlation exists between percentage of juice in the edible portion of the fruit and the pressure values. Thus a direct correlation is present between tenderness of the flesh and juiciness.

To adapt tenderness tests to legal maturity standards for grapefruit will require the manufacture of a special type of pressure tester. Further studies are being delayed until such an instrument is available.

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The Fig-Variety Character, Flattened Neck

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THE neck of a fig fruit or syconium, if present at all, is that part between the body and the stalk. It is most commonly round in cross section although in some figs it is angular. Some syconia have a neck which is characteristically compressed or flattened. This character is so pronounced and so constant as to make it of importance in recognizing certain varieties of *Ficus Carica.* It is for this reason that the following account of its occurrence and inheritance is presented.

In his suggestions for describing varieties of figs, Gustav Eisen (2) stated that the neck may be thin, slender, or "compressed sideways." In a recent publication by the author (1), attention is called to the fact that "the neck of some figs is characteristically compressed or flattened laterally, as in Calimyrna and many of its seedlings such as Maslin caprifigs No. 147 and No. 148. Some common figs also have a flattened neck, examples being Bourjassotte and Martinique." No other references to this character have been found in fig literature.

OCCURRENCE IN SMYRNA-TYPE FIGS

Flattening of neck is especially pronounced in syconia of Lob Injir (Calimyrna). The neck of this variety is short but prominent and conspicuously flattened as if the sides were pinched together. Eisen (2) does not use the word "flattened", but it is possible he had this in mind when he described Lob Injir as having a "neck thin, distinct but short, generally straight". Rixford (3) also uses the term "thin" to describe the necks of Lob Injir and that of the Eisen variety. Stanford has a short, decidedly flattened neck. The neck of Smirnsky, P. I.[1] No. 101721, introduced from South Russia, is somewhat flattened. Snowden has a prominent, curved neck up to ⅝ inch in length, and somewhat flattened. Sultane du Marabout, P. I. No. 77480, introduced from Algeria, also has a prominent, curved neck occasionally flattened.

Syconia of *Ficus palmata,* a near relative of *F. Carica,* are of the Smyrna type, that is, nonparthenocarpic. One variety of *F. palmata* bears edible syconia with a slender neck up to 1 inch in length, usually conspicuously flattened. The character, flattened neck, is common in seedling fruits of *F. palmata* although angular or triangular neck is still more commonly found. Thus, syconia of P. I. No. 72887, introduced from the Punjab, India, have a short, slender, angular or sometimes flattened neck.

OCCURRENCE IN COMMON FIGS

Flattened neck is a character sufficiently constant in some common figs, to make it useful in a key for identification of varieties. The neck of Panaché especially in green figs, is commonly flattened, the average measurement of ten syconia showing 5.77 millimeters short diameter and 6.77 millimeters long diameter. Baalie, P. I. No. 6467, is a small, purple fig with thin neck averaging 3.50 millimeters one diameter and 4.76 millimeters the other. Four dark-colored figs, Toulousienne, P. I. No. 18895; Martinique, No. 18884; Bourjassotte, No. 86794; and Barnisotte, No. 69009, all have necks flattened in a considerable percentage of specimens. The green figs, Bontard, No. 18836, and Ischia Green, both have decidedly flattened necks. In Grassale, No. 18883, flattening is characteristic of the fruit stalk as well as neck. Brebas or first crop figs of Grise Savantine, No. 18865, have necks up to ½ inch long and decidedly flattened.

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[1] P. I. refers to numbers of United States Department of Agriculture, Bureau of Plant Industry, Division of Plant Exploration and Introduction.

Occurrence in Caprifigs

The character, flattened neck, is prominent in some varieties of caprifigs both in the profichi and in the mamme crops, and in the white-fleshed as well as in the purple-fleshed varieties. It is especially characteristic of Roeding No. 4 and of Forbes, both purple fleshed. The flattened neck of Roeding No. 4 mamme figs measures 4.25 millimeters one thickness and 5.75 millimeters the other. In mamme figs of Forbes the neck is short and thin, averaging 2.82 millimeters the thin diameter, and 3.87 millimeters the thick diameter. The white-fleshed mamme figs of Figue Jaune, No. 86803, introduced from South Russia have a thick neck moderately flattened in some specimens. One variety of *Ficus palmata* has mamme figs with long stalks and triangular necks, with only occasional specimens showing flattening of the neck. Brawley, another variety of *F. palmata,* produces white-fleshed mamme figs with short stalk and short neck moderately flattened, the short diameter averaging 4.22 millimeters and the long diameter 4.75 millimeters. Flattened neck is also characteristic of the profichi crop of Markarian No. 2 and Markarian No. 3, both white fleshed.

Inheritance of the Character, Flattened Neck

Since syconia of Lob Injir (Calimyrna) have a prominently flattened neck, it is to be expected that its seedlings would also commonly show this character. This proves to be true in a number of seedlings from the Maslin seedling fig orchard started from seeds of imported Smyrna figs and planted at Loomis, California. Seven Maslin caprifigs out of eight available for study during the past few years show flattening of the neck more or less prominently. In 13 mamme figs of Maslin No. 141, the necks average 4.83 millimeters diameter of the thin axis, and 6.66 millimeters the thick axis. In 20 mamme figs of Maslin No. 144, or Mason, comparable measurements show 5.24 millimeters, and 6.96 millimeters in neck thickness. In mamme figs of Maslin No. 147, or Loomis, flattened neck is present but is not so prominent as in the two Maslin varieties just mentioned.

A few years ago syconia of several Calimyrna fig trees were pollinated with pollen of nine different varieties of caprifigs, six of the pollen parents having fruits with necks not flattened and three bearing fruits with necks prominently flattened. Table I gives the results respecting the character, flattened neck, in the F_1 progeny.

Calimyrna with prominently flattened neck, crossed with six caprifigs having neck not flattened, produced in the F_1 progeny, 382 seedlings with neck. Of these seedlings, 309 or 80.8 per cent had the neck more or less flattened. Calimyrna crossed with three caprifigs having the neck distinctly flattened, produced an F_1 progeny of 205 seedlings with neck, of which 183 or 89.2 per cent had the neck flattened. When the proportion of "flat neck" to the total number with neck, is calculated for each of the nine progenies and these are divided into two groups (male parent with flat neck and male parent with neck not flat), the application of the t-test (Snedecor) indicates no significant difference between the two groups.

TABLE I—THE F_1 PROGENY OF CALIMYRNA CROSSED WITH NINE VARIETIES OF CAPRIFIGS, IN RESPECT TO THE CHARACTER, FLATTENED NECK. CAPRIFIG PARENTS NOS. 1–6, NECKS NOT FLATTENED; CAPRIFIG PARENTS NOS. 7 TO 9, NECKS FLATTENED

Caprifig Parent	Total Seedlings		Total Caprifigs		Total Edible		Total
	Without Neck	With Neck	Neck Flat	Neck Not Flat	Neck Flat	Neck Not Flat	Neck Flat
Palmata	11	65	31	6	13	15	44
Kearney	29	50	27	8	11	4	38
Roeding 3	44	66	46	3	11	6	57
Stanford	47	51	38	4	7	2	45
Pseudo-Carica	16	82	42	4	22	14	64
Samson	50	68	49	1	12	6	61
	197	382	233	26	76	47	309
Maslin No. 148	13	67	53	1	12	1	65
Brawley	33	70	41	1	14	14	55
Forbes	28	68	46	4	17	1	63
	74	205	140	6	43	16	183

The proportion of seedlings bearing caprifigs—(those with short-styled flowers) to those bearing edible figs—(those with long-styled flowers) is almost exactly half and half. On the other hand, the number of caprifigs showing flattened neck is 63.5 per cent of the total while edible figs showing this character are only 20.2 per cent of the total with neck.

SUMMARY

The fig-variety character, flattened neck, is commonly found in syconia of Smyrna-type figs, common figs, and caprifigs. No mention of this character is found in pomological descriptions of figs, although terms such as thin, slender, or narrow are used. Studies of varieties of *Ficus Carica* show that flattened neck is such a constant character that it can be used in articial keys for identification of varieties. It is a dominant character in syconia of Calimyrna and its seedlings. Calimyrna, crossed with nine different varieties of caprifigs having neck not flat, shows the character flattened neck in 80.9 per cent of the F_1 progeny. Calimyrna, crossed with three caprifigs having neck prominently flattened, shows this character in 89.2 per cent of the F_1, a difference probably not significant when viewed statistically.

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Pecan Cracking Test

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RECENT improvements in pecan cracking machinery has made possible a greater use of native or seedling pecans. The expense of shelling is lower and growers receive a more satisfactory price than formerly. The demand is for oblong, thin shelled pecans suitable for cracking because of high kernel percentage and clean separation of kernels and shells. The size of the nut is not as important for cracking nuts as is the case with nuts to be sold to the consumer in the shell. The pecan market in due time may buy on grades relative to cracking quality rather than on size.

The object of this study was primarily to gain information regarding characteristics of natives and improved varieties which contributed to their desirability for cracking. The factors tested were the pressure required to crack, kernel percentage, size of nuts as indicated by number per pound, and how soaking nuts in water affects cracking.

METHODS AND MATERIALS

A cracking meter was designed and constructed from a screw type cracker. A hydraulic gauge was attached to the cracker having a valve located in a position to hold the indicator hand until released. Pressure applied to crack a nut is conveyed into the gauge through a liquid and thus indicated or read on the gauge as units. These units of pressure may be converted to pounds per square inch by multiplying by the area of the cylinder head in square inches. The area of the cylinder head was 1.23 square inches.

A preliminary test was made to determine the number of nuts required to give a representative sample for cracking pressure. Five samples of seedlings of variable size and shape were used for the test. The first sample consisted of 100 nuts. Since breakage of kernels indicated the nuts were too dry, a second sample was conditioned by soaking in water for 15 hours. In this case, only 50 nuts were cracked because of an insufficient supply of the same natives. Table I shows results secured. The analysis of data indicated that 60 specimens would be sufficient for a 10 per cent difference to be significant. Since the number of samples used in this preliminary test was relatively small it was determined to make use of samples consisting of 75 nuts each for the cracking tests.

One pound sample was secured from all the varieties and native seedlings located on the Oklahoma Experiment Station grounds. The number of nuts per pound and kernel percentage were recorded for 1935, 1937, 1939 and 1940 crops. Cracking pressures were recorded for samples of nuts produced in 1939 and 1940. The samples from the 1939 crop became very dry before cracking. This was indicated by a large percentage of broken kernels and high cracking pressure. Consequently, they were conditioned by soaking in water. Soaking in water

TABLE I—RESULTS OF CRACKING PRESSURE TEST TO DETERMINE THE NUMBER OF NUTS NEEDED FOR A SAMPLE FROM NATIVE PECANS

Native Number*	Number Nuts Per Pound	Kernel (Per Cent)	Mean Cracking Pressure†	Coefficient of Variation	Number Nuts Needed	
					10 Per Cent D.F.	20 Per Cent D.F.
243a	124	31.98	143.6	36.42	92	23
243b	106	32.85	87.3	25.63	47	12
255a	180	38.89	67.9	27.17	51	13
255b	159	40.63	53.8	26.29	48	12
553a	126	49.69	92.6	35.31	86	22
553b	107	48.12	67.3	24.29	42	11
692a	146	34.27	153.8	25.52	45	12
692b	134	34.67	122.1	23.10	38	10
923a	105	38.84	102.7	35.10	85	22
923b	94	37.22	59.6	24.16	43	11

*a Sample tested dry; b sample tested after soaking 15 hours in water.
†Pressure readings in units from gauge. To convert into pounds per square inch multiply by 1.23.

for 15 hours eliminated the largest part of the breakage of kernels and resulted in a lower mean cracking pressure.

Well cured samples from the 1940 crop were stored in air-tight containers until cracked. Sufficient moisture for good cracking was thus retained and no additional soaking was necessary. Tables II, III and IV give the data for some of the native seedlings.

The effect of time of soaking with reference to the cracking pressure and the percentage of broken kernels was determined on some varieties of the 1939 crop. The nuts were soaked for 4- and 15-hour periods. After soaking and cracking, the nuts were allowed to fall over an inclined ⅜-inch hardware cloth screen. The whole kernels which did not adhere to the shells were recorded as per cent of "screened kernels". The others were separated from the shells and recorded as per cent of "picked and broken kernels". Since without soaking, nearly 100 per cent of the kernels were broken, only the cracking pressure was recorded. Only a few varieties were cracked without soaking. Table VI indicates the results of time of soaking on improved varieties of 1939 crop.

RESULTS AND CONCLUSIONS

The data shows a wide variation in natives as to size, cracking pressure and kernel percentage. The cracking pressure was quite variable within each sample, running from 15 to 285 units on the gauge. This indicates the necessity of using a large sample in order to secure accurate results. With the same thickness of the shell, round nuts have a lower cracking pressure than oblong nuts. The greater the curvature of the shell, the less resistance in cracking; or as the length of the nut decreases, and the width increases, the less pressure required for cracking. All nuts will crack easier from the sides than from the ends.

If nuts are well-filled, a low cracking pressure normally indicates high kernel percentage. This relationship is shown in Tables II and III. The native No. 553 which was among the lowest with a mean cracking pressure of 75.68 tested 53.72 per cent kernel. No. 376 which required the highest mean cracking pressure (176.29) tested 37.68

TABLE II—NATIVE PECANS FROM STATION GROVE HAVING THE HIGHEST FOUR-YEAR AVERAGE ON KERNEL PERCENTAGE (1935, 1937, 1939 AND 1940) WITH TWO-YEAR AVERAGE OF MEAN CRACKING PRESSURE (1939–1940) AND THE NUMBER OF NUTS PER POUND

Native	Kernels (Per Cent)	Mean Cracking Pressure	Number Nuts Per Pound
553	53.72	75.68	114
484	53.37	78.51	135
231	52.16	50.04	146
624	51.93	86.64	155
235	50.66	49.55	131
646	50.39	67.33	96
461	49.14	78.08	92
842	48.94	52.47	119
696	47.93	98.18	110
353	47.86	99.07	122
211	47.77	72.75	120
915	47.71	78.96	114
591	47.65	62.05	127
428	47.60	67.95	108
331	47.52	83.15	129
463	47.51	57.50	105
903	47.52	67.67	148
412	37.38	38.10	136
653	47.18	68.12	148
700	47.14	77.93	127
401	47.02	76.37	108
432	47.00	60.73	142
152	46.98	91.93	110
490	46.96	61.13	134
730	46.90	66.93	127
326	46.90	109.20	120
363	46.89	46.38	105
165	46.78	107.70	112
213	46.75	81.04	132
574	46.67	95.40	102
598	46 60	64.63	113

TABLE III—NATIVE PECANS FROM STATION GROVE HAVING THE HIGHEST TWO-YEAR AVERAGE MEAN CRACKING PRESSURE (1939 AND 1940) WITH A FOUR-YEAR AVERAGE ON PER CENT KERNELS AND NUMBER NUTS PER POUND (1935, 1937, 1939, 1940)

Native Number	Mean Cracking Pressure	Kernels (Per Cent)	Number Nuts Per Pound
376	176.29	37.68	105
746	166.74	40.86	96
479	162.54	35.53	133
105	147.42	40.76	125
692	136.50	36.79	149
289	134.57	40.86	96
121	133.76	41.09	124
718	131.60	42.35	102
197	130.49	33.57	164
907	129.80	39.07	132
398	128.03	37.29	139
708	127.98	36.47	120
159	125.50	42.29	123
292	125.23	38.86	157
977	125.06	45.27	112
242	123.57	40.86	108
493	123.27	36.53	120
985	122.17	43.61	103
935	121.04	35.53	130
385	120.24	40.60	126

per cent kernels. Tree No. A 120, a very small nut, not shown in tables, had the lowest mean cracking pressure of 24.52 and tested 40.04 per cent kernel. If the cracking pressure and kernel percentage are both low, the kernels are likely to be shriveled from immaturity or some other cause.

The largest nuts in the native grove did not prove to be the best for cracking because all have a thick shell which resulted in lowered kernel percentage and higher cracking pressure. The largest nuts from the native grove as shown in Table IV are numbers 874 and 539 with 85 nuts each per pound.

Of all the varieties for which records are shown in Table V, the

TABLE IV—FOUR-YEAR AVERAGE OF THE LARGEST NATIVES FROM THE STATION GROVE

Native Number	Number Nuts Per Pound	Kernels (Per Cent)	Mean Cracking Pressure
874	85	46.36	97.61
539	85	43.33	94.16
440	86	42.33	104.85
793	86	42.22	100.21
368	87	44.66	112.36
521	87	37.70	79.93
498	88	41.53	103.84
439	88	46.25	90.23
743	90	40.20	98.00
883	91	45.99	108.71

TABLE V—THE NUMBER OF NUTS PER POUND, KERNEL PERCENTAGE AND CRACKING PRESSURE FOR IMPROVED VARIETIES

Varieties	1939*			1940		
	Number Nuts Per Pound	Kernel (Per Cent)	Mean Cracking Pressure	Number Nuts Per Pound	Kernel (Per Cent)	Mean Cracking Pressure
Burkett	50	51.37	75.35	55	50.61	86.20
Busseron	62	46.95	111.07	68	46.09	96.91
Delmas	54	44.16	97.74	53	48.64	71.14
Early Bird	—	—	—	79	51.88	53.16
Schley	66	56.48	41.15	58	57.95	44.91
Green River	80	48.70	111.81	69	51.10	83.46
Halbert	62	56.59	81.84	69	58.90	63.96
Jersey	58	55.13	37.97	—	—	—
Kentucky	—	—	—	63	47.19	71.19
Love	44	53.29	124.80	—	—	—
Mahan	46	47.24	60.46	—	—	—
Manture	54	46.10	107.26	56	47.47	64.70
Major	57	44.53	104.27	65	50.74	118.29
Moneymaker	66	41.89	111.92	53	42.50	169.49
Moore	91	46.09	61.07	76	48.58	61.51
Nuggett	92	57.76	44.55	85	59.01	52.35
Oklahoma	55	43.38	109.29	55	48.69	70.04
Posey	53	54.34	55.75	55	52.52	71.39
San Saba	—	—	—	98	58.24	35.98
San Saba Improved	62	55.93	68.76	71	54.70	56.46
Success	42	50.29	127.79	42	52.00	82.07
Stuart	45	47.13	92.05	43	47.28	132.00
Squirrels Delight	54	52.38	84.41	44	55.29	109.09
Number 60	76	57.32	70.57	—	—	—
Texas Prolific	56	52.22	82.29	54	55.26	98.94
Van Deman	—	—	—	54	43.12	112.69
Warrick	63	47.91	102.06	70	45.61	113.09
Western Schley	61	54.71	50.68	—	—	—

*Soaked in water for 15 hours.

Nuggett had the highest kernel percentage. The nut is small as compared to the other varieties, having a very low cracking pressure. The Jersey and Schley had lower cracking pressures than the Nuggett. The Moneymaker, a very thick shelled pecan, had the lowest kernel percentage and the highest cracking pressure of all tested. The 1939 crop was somewhat immature due to climatic conditions, and had a lower kernel percentage and cracking pressure than the 1940 crop.

As nuts dry, the cracking pressure and the number of broken kernels increases. The Schley, when dry, had a cracking pressure of 62.03 but upon soaking for 4 hours, the pressure required for cracking dropped to 24.81. As soaking continued up to 15 hours, the cracking pressure increased to 41.15. This indicates that soaking decreases the resistance of the shell, and suggests that the increased pressure required for cracking is due to the absorption of moisture by the kernel, thereby causing it to swell and fill the shell more snugly. A 4-hour soaking period did not prevent the breakage of kernels upon cracking. They were still dry and brittle and broke when the nuts were cracked. After 15 hours of soaking, the kernels had absorbed sufficient moisture to make them more pliable. The San Saba Improved, Nuggett and Moore were the best cracking varieties tested from the standpoint of whole kernel percentage after extraction. The Squirrels Delight and Mahan were the poorest tested. The kernels from the 15-hour soaking treatment required drying to prevent molding.

TABLE VI—Effect of Soaking on Kernel Breakage and Cracking Pressure

Variety	No Soaking Mean Cracking Pressure	4 Hours				15 Hours			
		Mean Cracking Pressure	Screened Kernels (Per Cent)	Picked Kernels (Per Cent)	Broken Kernels (Per Cent)	Mean Cracking Pressure	Screened Kernels (Per Cent)	Picked Kernels (Per Cent)	Broken Kernels (Per Cent)
San Saba Improved	——	59.05	0.0	20.37	78.63	68.76	0.0	96.77	3.23
Nuggett	——	44.55	0.0	20.40	79.60	——	0.0	95.88	4.12
Moore	——	38.55	18.12	34.84	47.06	61.07	4.49	91.02	4.49
Schley	62.03	24.81	0.0	17.54	82.46	41.15	1.17	90.33	8.50
Texas Prolific	108.10	42.04	0.0	26.18	74.82	82.29	0.0	85.91	14.09
Halbert	72.52	40.24	0.0	19.07	80.92	81.94	0.0	74.72	25.28
Stuart	——	85.79	0.0	17.44	82.56	72.05	0.0	71.57	28.43
Western Schley	——	38.82	1.10	15.32	83.58	50.68	0.0	67.77	32.23
Squirrels Delight	——	78.00	0.0	0.0	100.00	84.41	0.0	65.99	34.01
Mahan	——	17.85	0.94	36.84	62.12	60.46	0.0	56.92	43.08

Conclusions

High kernel percentage and low cracking pressure are related if the size of the nut is relatively small. The best shellers are varieties and native seedlings having low cracking pressure, high kernel percentage and an oblong shape. The cracking pressure varies greatly within the sample. Sixty specimens were needed to give a significant difference on the 10 per cent level. The mean cracking pressure of native seedlings from the Station grove varied from 24.52 to 176.29 units on the gauge, or 30.15 to 216.83 pounds per square inch. The pressure readings as indicated from the meter can be converted over to pounds per square inch by multiplying by 1.23. Storing pecans in air tight containers soon after harvest will retain sufficient moisture to encourage whole kernel extraction. The cracking pressure of pecans thus stored could not be altered by conditioning the sample.

Ascorbic Acid Content of Walnut Hulls[1]

By ELMER HANSEN, *Oregon Agricultural Experiment Station, Corvallis, Ore.*

GERGELEZHIU (2) has reported green walnut hulls to contain 500 to 2549 milligrams of ascorbic acid per 100 grams fresh weight. These values are much higher than those reported for any edible fruit or vegetable and are comparable to the ascorbic acid content of rose hips in England and Scotland (1). Since walnuts constitute a major crop in several sections of the Pacific coast, large quantities of crude walnut hulls are available in case the vitamin C from this source could be utilized for nutritional purposes.

MATERIALS AND METHODS

The nuts used for analyses were picked from trees grown on the Oregon Experiment Station variety plot at Corvallis. The English walnuts at time of picking were mature, the involucres (hulls) dehiscing and separating readily from the exocarp. Samples of the Eastern black walnut, *J. nigra, Linn.*, and the northern California black walnut, *J. californica*, var. *Hindsii, Jepson,* were picked from the trees shortly before the nuts had begun to drop freely. Since these two species are indehiscent, the hulls were pared from the exocarps by means of a sharp knife.

Ascorbic acid was determined by dye titration of filtered aliquots of the samples ground in a Waring blendor with 3 per cent metaphosphoric acid (3).

Moisture content was determined on 50-gram samples dried in a ventilated oven for 12 hours at 70 degrees C, then in vacuo to constant weight.

RESULTS

The ascorbic acid content, expressed on both fresh and dry weight basis, are given in Table I.

TABLE I—ASCORBIC ACID CONTENT OF WALNUT HULLS

Species and Variety	Per Cent Moisture	Mg Ascorbic Acid Per 100 Gm Fresh Weight	Per Cent Ascorbic Acid (Dry Weight)
Juglans nigra	89.96	837.6	8.34
Juglans californica*, var. *Hindsii	86.00	628.3	4.49
Juglans regia			
Franquette	90.00	486.8	4.87
Meylan	89.12	604.9	5.59
Mayquette	88.82	569.3	5.60
Mayette	87.80	512.5	4.20
Eureka	88.12	526.7	4.41

These data show that the involucres of walnuts are high in ascorbic acid. On a fresh weight basis, the values compare favorably to those reported for rose hips. On a dry weight basis, walnut hulls are a much richer source, since they contain approximately 86 to 90 per cent moisture, while rose hips contain approximately 40 to 50 per cent moisture.

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Notes and Observations from a Study of Water Core in Illinois Apples During the 1942 Season

By Dillon S. Brown, *University of Illinois, Urbana, Ill.*

THE occurrence and characteristics of water core in a number of varieties of apples were studied during the 1942 season. Observations were made and samples were collected in commercial orchards in southern Illinois and in the University orchards at Urbana. This report presents certain general observations and suggestions arising from these observations as they relate to the development of water core in apples under Illinois conditions. Details of the study will be reserved until additional information has been secured.

The term water core seems to be a misnomer. In most varieties studied the affected tissues were confined largely to the cortex. Winesap and Stayman Winesap were the only two varieties in which the affected tissues were predominately in the core. Further, there were indications that materials in addition to water were involved, so that the descriptive term water core, both from the standpoint of the substances involved and the tissues affected, is misleading.

Regardless of the tissues involved, whether cortex or core, the incidence of water core was always associated with the vascular supply of the apple. In most varieties, water-cored areas appeared first around the toral bundles or the traces which diverge from them into the flesh. In Winesap and Stayman Winesap, the ventral carpellary bundles were involved, especially in that region of the fruit near the stem where the toral bundles and the carpellary bundles diverge.

It has been suggested (2, 3) that a rapid conversion of starch to sugar within the apple may contribute to the initiation of water core. Observations this season on Illinois apples do not confirm this conclusion. Sections of apples were tested for starch with the iodine-potassium-iodide reagent. In every instance, the amount of starch in the water-cored areas appeared to be equal to, or sometimes greater than, that in the non-water-cored tissues. Of course, only small changes in the amount of sugar in the tissues might be sufficient to account for changes in osmotic pressure which might result in water core, so that any macroscopic estimation of starch may be inadequate. However, the normal conversion of starch as the fruit matured also was not associated with the incidence of the disorder. Water core was observed in some fruit long before there was any evidence of a decrease in starch anywhere in the cortex; that is, water core appeared in apples that were immature as judged by the starch test. In addition, as the fruit matured, the regions around the vascular supply to the cortex were among the last to be freed of starch, and these were the same areas in which water core first appeared.

In regard to the relation between maturity and the occurrence of water core, it appeared that in general the number or proportion of affected apples, both those in which the water core could be seen without cutting into the fruit as well as those in which it could be determined only by sectioning, increased as the fruit became more mature.

Some water core was found in the varieties Duchess, Transparent, and Willow Twig a month to 6 weeks before the crops were harvested. However, the disorder was not serious until most of the fruits were ripe and, in the Transparent, until they were nearly overripe. It may be that relative to water core we need to revise our ideas of maturity; that is, if water core is associated with maturity, the apples which water-core long before harvest time must reach a stage of maturity which is further advanced than other fruit on the tree.

Maturity probably is associated also with the apparent relation between the exposure of the fruit to sunlight and the prevalence of water core (1, 2). It was observed that, in general, the exposed fruits were more apt to be water-cored than were shaded fruits, but the differences were not always consistent, especially with Duchess. Some of the most severely water-cored fruits were found in the shadiest portions of the trees. However, whether fruits were taken from exposed or shaded parts of a tree, the water-cored fruits were relatively more mature than non-water-cored apples from the same position, as indicated by tests of soluble solids, titratable acidity and dry weight. Samples of water-cored apples were higher in percentage of dry matter than non-water-cored apples picked at the same time. The juice expressed from a ground sample of water-cored fruits was usually higher in soluble solids and lower in titratable acid than the juice from non-water-cored apples. These differences indicate that the water-cored fruits were more mature, since an increase in dry matter and soluble solids and a decrease in acid is usually associated with maturity. As the entire crop became more mature, the magnitude of the differences in dry matter, solids and acid between the water-cored and non-water-cored apples usually decreased. By the same standards exposed fruits were usually more mature than shaded fruits. The effects of light and temperature in relation to water core, therefore, were apparently indirect, and the exposed fruit was more susceptible to water core merely because of an advanced maturity.

The soluble solids should be related to the starch to sugar change if that is involved in the incidence of water core. On the basis of individual apples, the water-cored tissues were not consistently higher, and were often lower, in soluble solids than the non-water-cored tissues of the same apple. This fact, together with the fact that as much and often more starch appeared to be in the water-cored than in the non-water-cored tissues would seem to indicate that the starch to sugar conversion *within the apple* was not important in the incidence of water core.

Other observations suggest that the source of water core was not in the apple itself or the result of changes which may have occurred within the apple. In making a detailed harvest of fruit on a Duchess tree, it was observed that the most severely water-cored apples were sticky on the surface. There was apparently a guttation of materials through the lenticels. A similar guttation was noted on Willow Twig apples later. In fact, on Willow Twig it was noted that the appearance of a small drop of a sticky, sweetish liquid on the surface of the apple was associated with a small pocket of water-cored tissue just beneath the skin; in many cases this was the only evidence of water core in the entire apple. On further observation of severely water-cored Duchess apples it was noticed that the stems of the fruit were often sticky and were somewhat more shiny or glassy in appearance than stems of non-water-cored apples. In addition, when such an apple was removed from the cluster base, there was an exudation of liquid from the end of the stem and also from the cluster base at the point from which the apple was removed. Such exudations were always greater from the cluster base which bore a water-cored apple than from one which bore a non-water-cored apple. Sections through the stems of water-cored apples and through the cluster bases which bore such apples gave some indication of a "water-cored" condition in the parenchyma tissues of these parts.

Although these observations will need confirmation in other seasons, they do suggest that perhaps too much attention has been devoted to changes that might occur within the fruit as a cause of water core. It seems more likely that something occurs in the tree, in the spur or cluster base, which causes an influx of water and solutes into the apple, under some sort of pressure, with the resultant filling of the intercellular spaces of the cortex or core, characteristic of water core. The fact that water core appeared in the fruit in connection with the vascular supply lends support to this suggestion. Also, the fact that the dry weight of water-cored apples was greater than that of non-water-cored apples is some indication that something besides water was entering the fruit and was associated with the occurrence of the disorder.

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Leaf Scorch and Die-Back of Apricots

By E. L. PROEBSTING and C. J. HANSEN, *University of California, Davis, Calif.*

THE occurrence of leaf scorch and die-back in a number of old apricot orchards in the Hollister Valley was called to our attention in the summer of 1938. The character of injury is illustrated in Fig. 1. The leaf symptoms vary in intensity from a cupping of the leaf to severe marginal scorch, followed by excision of the dead marginal tissue. Affected leaves are small. When death of branches occurs, it is usually in the period May to July. This condition apparently had been present on certain trees in these orchards for some years but acute symptoms over a wide area had developed only recently. Because of the similarity of these symptoms to those of prune die-back caused by potassium deficiency, Mr. R. D. McCallum, Farm Advisor for San Benito County, had treated several badly scorched trees with potassium. He had likewise treated several trees with sulfur to counteract any alkali effect that might be present, some of the orchards concerned being known to have sodium carbonate present in the soil. These treatments were not effective.

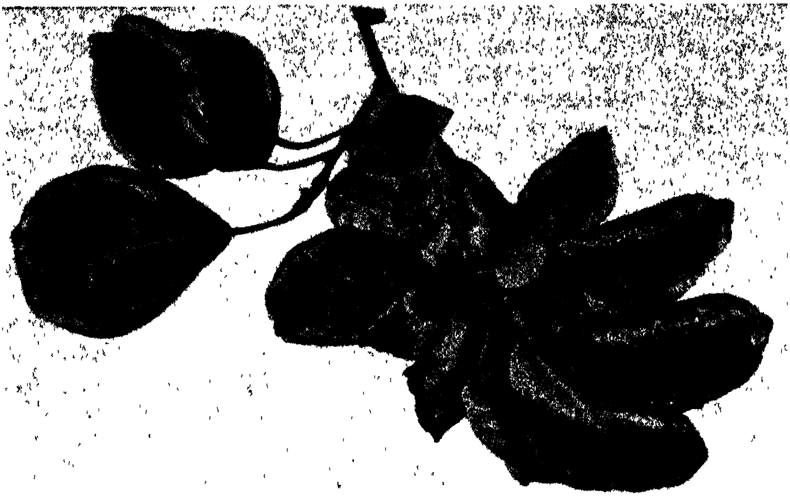

FIG. 1. Typical leaf scorch of apricot on Myrobalan.

Six orchards were examined, all of which showed more or less of the trouble. Chemical analyses of soil samples showed sufficient alkali in three of them to suggest injury from that cause. Two of these orchards were on Dublin clay adobe and one on Rincon clay. The latter orchard, in addition, contained excessive amounts of boron. The other three were on Yolo silty clay loam, a deep, well drained, fertile soil free from either alkali or boron. Two of the latter were selected for further investigation because of the absence of complicating conditions.

A mixture of minor elements containing copper sulfate, boric acid, manganous sulfate, ammonium molybdate, zinc sulfate, thorium nitrate, barium chloride, sodium tungstate, potassium dichromate, cadmium sulfate and cobaltous acetate was injected at two dilutions into scaffold branches of several trees. Injections of a mixture of the first five of these were also made. No responses were obtained.

The affected orchards had all been propagated on Myrobalan rootstock, which is commonly used for apricots on heavy or wet soils. It has not proven entirely satisfactory, although many trees have continued in commercial production beyond fifty years on this root. The character of these defective unions has been described by one of us (1).

The severity of scorch seemed to vary from year to year on given trees. There was generally less in 1940 and 1941 than in 1938 and 1939. It was also noted that young trees on apricot root, replanted where others had died, showed none of the trouble.

It was noted that some of the trees which were in excellent condition had developed scion roots, which suggested a stock relationship. Twenty-five trees in one orchard which were planted about 1915 were, therefore, inarched with apricot seedlings, four seedlings per tree in January 1939. These trees varied in severity of injury from trees which were nearly dead to those with little damage. Trees of different degrees of injury were selected because it was feared the

TABLE I—Apricot Trees Inarched with Apricot Seedlings January 11, 1939

Tree Number	Tree Condition*				Remarks
	May 24, 1939	Aug 8, 1940	Jun 5, 1941	Jun 8, 1942	
1	1	2	1	1	Three inarches; no scorch
2	1	2	1	1	No inarches; good tree
3	4	4	1	2	Good growth over 2 inarches; little growth on other side
4	3	2	2	2	One branch poor but good over inarches
5	2	3	2	4	Two inarches, best growth over inarches
6	3	4	3	3	Two good inarches feed 1 side; good on that side, badly scorched on other
7	4	5	3	3	Two inarches on 1 side. Good recovery there; badly scorched on other side
8	2	2	1	1	One inarch; tree in good condition
9	3	3	2	2	Two inarches. Best over them
10	4	3	1	1	Three inarches. Good recovery
11	2	4	3	4	No inarches; little growth; cupping
12	4	4	3	3	Two inarches. Best over them
13	2	1	1	1	Three inarches. Good condition
14	4	3	2	1	One branch bad; good over inarch
15	5	4	2	2	Good over inarch; poor on other side
16	4	3	1	2	Good recovery; perhaps best opposite 2 inarches
17	2	2	2	1	Two weak inarches; good condition
18	2	2	1	1	One weak inarch; good condition
19	3	3	2	1	Two inarches; good condition
20	2	2	1	1	Two strong inarches; good condition
21	3	2	2	1	Two inarches; good condition
22	2	1	2	2	One inarch; good throughout
23	3	2	2	3	No inarches; tree going back
24	3	1	1	2	Four inarches; good throughout
25	3	3	2	3	Four inarches; fair except on one branch without inarch connection

*For explanation of grade numbers, see text. Some apparent discrepancies are due to averaging all parts of a tree. For example, tree 5 has improved above the inarches, but become worse where they failed. The average tree condition is, therefore, down.

badly damaged trees might die before the inarches became large enough to affect the situation.

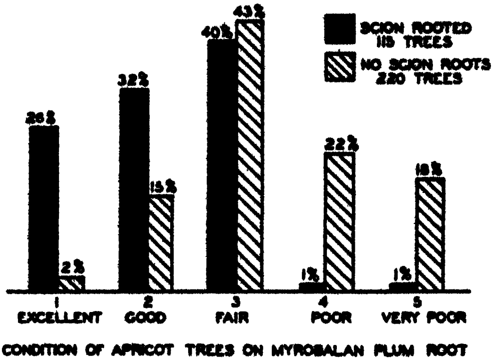

FIG. 2. Results of survey indicating the incidence of scion roots and their relation to tree condition.

A survey of the orchard, in which the inarching was done, was made to determine the incidence of scion roots and their relation to tree condition. Trees were classified in five groups, class 1 being excellent trees, class 5 barely alive, and the others intermediate. The results are shown in Fig. 2.

These figures show clearly a relationship between scion roots and freedom from scorch. The small number of class 4 and class 5 trees in the scion rooted group is especially striking in view of the fact that all scion rooted trees, no matter how small the root, were included in this group. The presence of a few excellent and good trees in the nonscion rooted group is to be expected on variable seedling stocks.

The results of the inarching are recorded in Table I.

These data show the condition of inarches after three and one-half years, and the improvement in tree condition associated with their development. The largest inarches were about 2 inches in diameter. Fig. 3 shows inarch development on one side of a tree. Fig. 4 shows the contrast between that side and the other where the inarch failed.

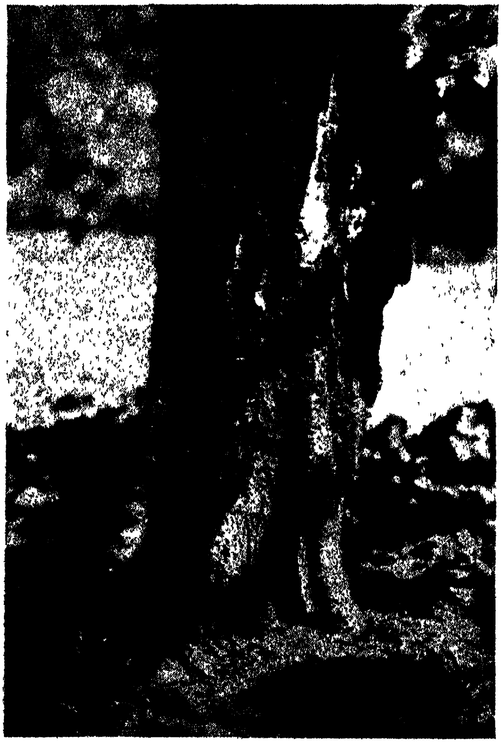

FIG. 3. Apricot inarches on apricot in their fourth year.

FIG. 4. Good growth of branch over inarches (right) compared with poor growth of remainder where inarches failed.

The above facts seem to establish the Myrobalan rootstock as the cause of the leaf scorch and die-back observed. The mechanism by which the injury is produced is obscure. Although evidence of structural defects of the union is apparent, it does not seem sufficient to account for this type of symptom. The fact that these trees have made moderately good growth for a long period of years before the onset of die-back, does not seem in accord with a mechanical interruption. On the other hand, the fact that scion roots correct or prevent the development of symptoms indicates that a specific substance transmitted from the roots is not the causative agent. The behavior is in contrast to that of Bartlett pear on Japanese root, where black-end is eliminated with inarches only after connection with the Japanese stock has been severed. Although the facts presented suggest a deficiency which is made good by the apricot roots, whether scion or inarch, none of the materials supplied the top by injection has been beneficial. This phase needs further exploration, however, before mineral deficiencies can be excluded.

The occurrence of this trouble in a group of orchards in one apricot district among trees planted about the same time might be due to use of seed from an unusual source by the nurseries which produced these trees. Myrobalan seedlings are known to be highly variable, and it is conceivable that certain trees might yield seeds producing this condition.

Mild symptoms, that is, leaf cupping and slight scorch, have been observed on one old tree on Myrobalan root in a Winters orchard in 1942. The tree had made little growth. There was some indication of a poor union.

SUMMARY

Many mature apricot trees in the Hollister Valley have shown a leaf scorch and die-back which could not be related to soil conditions.

It has been found only on trees propagated on Myrobalan root. Trees on this root which have formed scion roots are usually better trees than those having none. Trees which have been inarched with apricot seedlings have shown marked recovery after 3½ years' growth.

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Arsenic Injury of Peach Trees

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IN Eastern Washington there is a widespread disorder of peach trees that resembles arsenical injury produced by spraying trees with soluble arsenic compounds. However, arsenical sprays are seldom applied to peaches in this region, and then only as a dormant spray. This disorder particularly affects young trees planted in old apple land where considerable amounts of lead arsenate spray residues have accumulated. After several years, these trees usually start to recover. As a general rule, injury does not take place until mid-summer and appears first on the older leaves, the terminals frequently remaining normal in appearance for some time. The injured leaves commonly show brown to brownish-red spots along the margins and between the veins. These spots usually dry and may fall out leaving shot holes and a notched emargination. When injury is severe, a variable amount of defoliation occurs. Often practically all the leaves have fallen in late August leaving the fruit hanging on bare limbs. The affected trees are commonly stunted and lacking in vigor.

Reeves and Hutchins (4), in their discussion of peach diseases in Washington, describe this disorder and attribute it to toxic materials in the soil (Group 5 and possibly Group 3 in their classification). Likewise, Blodgett (2) has reported arsenic injury to trees on old apple land in Idaho, and has obtained similar leaf symptoms by soil treatment of potted plants with lead arsenate. Previously, Vandecaveye and coworkers (5) studied unproductiveness of old apple land planted to barley and alfalfa and attributed it to the soluble arsenic content of the soil. The lead residue seemed to have little effect on the plants. Thus all available evidence pointed to arsenic as the probable cause of this disorder in peach. This study was initiated in order to test this conclusion and to differentiate this disorder from diseases, such as Western X-disease of peaches, that might be confused with it.

In the summer of 1942, young peach trees growing on non-toxic soil were injected with sodium arsenate in amounts ranging from 10 milligrams to 1 gram. Leaf injury resulted in all cases and the symptoms produced were similar to those which occurred on trees growing in toxic soil. The larger injections caused almost complete defoliation and killed some of the branches outright. The injection of similar amounts of lead acetate produced no observable injury.

A preliminary analysis of leaves of trees growing on toxic soil in comparison with normal leaves, showed no appreciable differences in nitrogen, potassium, phosphorus, calcium, or magnesium. Leaf and soil samples were then collected in an attempt to correlate the arsenic content of foliage and of soil with the symptoms. The method of Williams and Whetstone (6) was followed in the analyses with the exception that the chloride distillation of the A.O.A.C. (1) was substituted for the bromide distillation. The soil samples were dried in a vacuum oven at 80 degrees C, sifted through a 20-mesh brass screen, and thoroughly mixed. They were analyzed for total arsenic

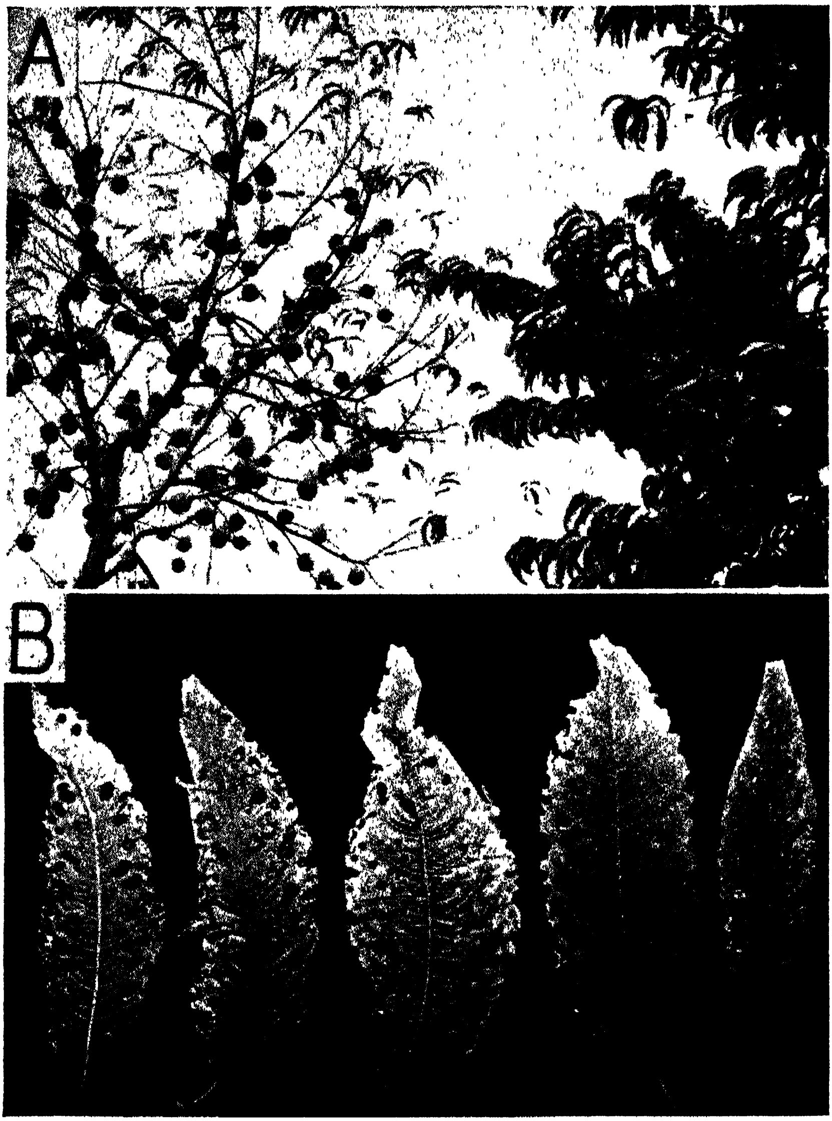

FIG. 1. Arsenic injury of peach trees. (A) Extreme defoliation of severely injured tree at left; normal tree at right. (B) Leaves with symptoms of arsenic injury that show marginal and interveinal burning and shot-holing.

and for water-soluble arsenic. The water soluble fraction was obtained by extracting 1 part of soil with 5 parts of water.

Leaf samples were treated very carefully before analysis in order to remove arsenic contamination present as dust on the leaf surfaces. There may be enough surface contamination on the leaves of plants near apple and pear orchards sprayed with lead arsenate to make errors up to several thousand per cent. Peach trees more than ½ mile away from the nearest apple and pear orchards had 200 to 300 per cent error due to surface contamination, while those ⅛ mile away had nearly 1000 per cent error. In actual amounts this contamination may be only a few micrograms of arsenic per leaf, but in relation to the extremely small amount of arsenic within the leaf, it is an enormous amount. Fortunately it is present in a fairly insoluble form and this, along with the low humidity occurring in Central Washington during the summer months, makes it probable that very little is absorbed by the leaf. In order to remove this contamination prior to analysis, freshly collected leaves were individually dipped in a 4 per cent solution of sodium hydroxide in 70 per cent alcohol for about 15 seconds and then rinsed with distilled water. When the leaves were washed with water alone, only a small amount of the surface contamination was removed. During the washing process the leaf was held by its petiole with clean forceps, and when washing was complete, the petiole was removed with clean scissors. The leaf samples were then dried in a vacuum oven at 80 degrees C, ground with a clean porcelain mortar and pestle, and thoroughly mixed before aliquots were taken for analysis. All analyses reported in this paper are the average of at least two determinations.

The presence of such relatively large amounts of arsenic on the surface of the leaves would lead one to doubt the validity of these leaf analyses for arsenic. However, the washing procedure reported here was found to be very effective (Table I). Duplicate leaf samples from trees that had very large surface contamination were found to check very closely after washing, either with 6 N nitric acid or with alcoholic sodium hydroxide. Furthermore, leaves not likely to have much contamination were found to lose only a small amount of arsenic on being washed; therefore, it is probable that very little arsenic was removed from within the leaf by the washing process.

TABLE I—EFFECT OF THE WASHING PROCEDURE ON THE ARSENIC CONTENT OF PEACH LEAVES (ARSENIC IN PARTS PER MILLION OF DRY LEAF MATTER)

Sample	Washing Procedure			
	Not Washed	Water	6 N HNO_3	4 Per Cent NaOH in 70 Per Cent Alcohol
Normal leaves from tree about 25 yards from apple orchard sprayed with lead arsenate	70.0	48.0	1.0	0.9
Normal leaves from tree in same block as above but about 175 yards from apple orchard	12.5	7.2	1.2	1.3
Normal leaves from tree about 5 miles from nearest apple orchard	1.4	—	1.0	1.0
Normal terminal leaves from tree ½ mile from nearest apple orchard	3.9	—	—	1.3
Injured basal leaves from same tree as above	5.1	—	—	2.4

Typical results of the leaf analyses, shown in Table II, indicate a direct correlation between injury and arsenic content. The extremely low margin of toxicity is striking. Leaves may have up to about 2 parts per million of the dry weight as arsenic and remain normal in appear-

TABLE II—ARSENIC CONTENT OF REPRESENTATIVE SAMPLES OF PEACH LEAVES

Sample	Arsenic in Parts Per Million Dry Matter
Normal leaves from young tree growing on old grazing land	1.0
Normal leaves from young tree growing on old alfalfa land (soil No. 2)*	1.0
Representative leaves from trees growing on same land as the preceding, that were injected with sodium arsenate and show typical arsenic injury	5.2
Moderately injured leaves from young trees growing on old apple land (soil No. 1)*	5.2
Moderately injured leaves from trees about 12 years old that are growing adjacent to old apple land through which irrigation water must run before reaching the peaches (soil No. 3)*	3.3
Normal appearing terminal leaves from young trees in old apple land	1.6
Moderately injured leaves lower down on same branches as the preceding	2.9
Normal appearing terminal leaves from young trees growing on land that had been out of apples for at least 15 years	1.3
Slightly injured leaves lower down on same branches as the preceding	2.4
Normal appearing terminal leaves from trees about 3 years old growing on old apple land	1.7
Moderately injured leaves lower down on same branches as the preceding	2.8

*See Table III.

ance, but above this amount injury will be apparent. Some of the data on the injured leaves may be somewhat misleading, for it is probable that the burnt and fallen tissue from shot-holed leaves had a higher arsenic content than the rest of the leaf.

Typical analyses of soil samples (Table III) show the large amount of spray residue arsenic which accumulated in the upper foot of soil in old apple land. Vandecaveye and co-workers (5) and Jones and Hatch (3) have reported similar results. The analyses also show that trees growing on previously non-toxic soil may be damaged by the accumulation of arsenic at the end of an irrigation run, probably from the water having picked up arsenic as it passed in furrows through toxic soil.

TABLE III—TOTAL AND WATER SOLUBLE ARSENIC CONTENT OF REPRESENTATIVE SOILS (ARSENIC CONTENT EXPRESSED AS PARTS PER MILLION OF THE DRY WEIGHT OF THE SOIL)

Sample	Total Arsenic	Water Soluble Arsenic
Soil No. 1—from old apple land where young peach trees show moderate to severe injury.		
Surface Soil (one inch)	174	3.6
0 to 12 inches	96	1.5
12 to 24 inches	21	0.4
24 to 36 inches	12	0.2
36 to 48 inches	8	0.0
Soil No. 2—from old alfalfa land where no apples had grown but small amounts of spray residue may have been washed in from an adjacent apple orchard. Young peach trees growing in this soil are normal and vigorous.		
Surface Soil (one inch)	9	0.1
0 to 12 inches	11	0.1
12 to 24 inches	8	0.1
24 to 36 inches	6	0.1
36 to 48 inches	5	0.0
Soil No. 3—from land where no apples had grown, but 12 year old peach trees growing there are badly injured. Irrigation water runs in furrows through old apple land before it reaches the peaches.		
Surface Soil (one inch)	17	1.0
0 to 12 inches	10	0.2
12 to 18 inches (gravel below this depth)	7	0.2

In addition to the peach, other fruit trees are also affected by arsenic, principally apricots (including the Yakimene) which show a very striking inter-veinal spotting and burning. There is a marked difference in susceptibility of different kinds of fruit trees to arsenic. Peaches and apricots are perhaps most easily injured; cherry is moderately damaged; plums, pears, and apples are more resistant. Leaves from plum trees growing in old apple land (soil No. 1 in Table III) had as much as 13.0 parts per million of arsenic but were making good growth and had no visible leaf symptoms. Severely injured apricot leaves in the same soil had 6.1 parts per million, while cherry leaves with slight marginal burning had 8.6 parts per million. Wilson (7) found that when fruit trees in California were sprayed with soluble arsenic compounds, almond was the most sensitive, apricot next, while plums and prunes were found to be fairly tolerant.

The evidence indicates that the disorder of peach trees reported here is due to absorption of small quantities of arsenic from the soil. Amounts of arsenic greater than 2 parts per million of the dry weight of the leaves have been found to be toxic. Since the peach tree is so sensitive to arsenic, it seems quite possible that the natural arsenic content of some soils may be high enough to cause injury.

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Effect of Time of Pruning on the Rate of Top Regeneration of Valencia Orange Trees

By S. H. CAMERON and R. W. HODGSON, *University of California, Los Angeles, Calif.*

IN a previous paper (3) reference was made to a study, then in progress, of the influence of time of pruning on the rate of top regeneration of Valencia orange trees. The results of that study, in so far as growth responses are concerned, are now available and constitute the basis of this report.

METHODS AND MATERIALS

The 24 trees used in this study were planted in May 1929. They were propagated by budding carefully selected nucellar seedlings of a sweet orange clone with buds all from one Valencia orange tree. They were in good health and unusually uniform in size, appearance and bearing behavior.

Two of the trees were pruned each month during 1939. One year after pruning (that is in the corresponding month of the following year) one tree of each pair was excavated by the "short-cut" method described in the previous paper. Fresh and dry weights of all parts were recorded and samples were preserved for subsequent laboratory determinations. Two years after pruning the remaining member of each pair was removed and handled in the same manner as those removed the first year.

The pruning was comparable with that described and illustrated as "heavy" in the previous paper (3). Five scaffold branches about 18 inches long were left to regenerate a new top. The prunings represented approximately two-thirds of the total fresh weight of the tree. Total tree weight was calculated by adding the weight of the prunings to the weight of the tree, less new top growth, at the time of digging. This does not take into account changes in weight of the residual parts of the tree. Such changes probably are slight and should, at least for the present study, be similar, because for each tree removed during a given year the interval between pruning and excavation was the same.

DATA AND DISCUSSION

All essential data relating to the fresh weights of the 24 trees together with calculated values showing the relationship between new top growth and total tree weight and between new top growth and weight of prunings are presented in Table I.

Although the trees appeared to be uniform in size in the orchard the total weight data indicate considerable variation. This variation can to a large degree be accounted for by the seasonal fluctuation in amount of leaves on the tree, which we have previously shown to be relatively low during autumn and early winter and high during spring and summer (2).

The data indicate a somewhat slower rate of top regeneration by trees pruned in autumn and early winter than at any other time

TABLE I—Effect of Time of Pruning on the Rate of Regeneration of New Top of 10-Year-Old Valencia Orange Trees

Date of Pruning (1939)	Fresh Weights (Grams)				Per Cent of Total			New Top as Per Cent of Prunings	
	Total Tree	Prunings	New Top		Prunings	New Top			
			First Year	Second Year		First Year	Second Year	First Year	Second Year
Jan. 17	196,539	134,719	19,840	—	68.5	10.1	—	14.7	—
	185,558	110,678	—	46,922	59.6	—	25.3	—	42.4
Feb. 21	178,516	117,936	19,454	—	66.1	10.9	—	16.5	—
	209,799	134,719	—	50,240	64.2	—	23.9	—	37.2
Mar. 16	213,060	148,780	19,569	—	69.8	9.1	—	13.1	—
	210,578	133,358	—	50,720	63.3	—	24.1	—	38.0
Apr. 14	169,992	112,492	27,776	—	66.2	16.3	—	24.6	—
	184,424	120,204	—	45,437	65.2	—	24.0	—	37.8
May 19	170,921	114,761	24,335	—	67.1	14.2	—	21.2	—
	217,380	147,420	—	57,950	67.8	—	26.6	—	39.3
Jun. 19	227,630	163,750	26,731	—	71.9	11.7	—	16.3	—
	232,164	154,224	—	69,480	66.4	—	29.9	—	45.0
Jul. 15	192,647	136,987	20,965	—	71.1	10.8	—	15.3	—
	213,485	144,245	—	55,200	67.5	—	25.8	—	38.2
Aug. 15	214,420	147,420	21,752	—	68.7	10.1	—	14 7	—
	188,994	125,194	—	45,322	66.2	—	23.9	—	36.2
Sep 19	211,886	145,606	18,143	—	68.7	8.5	—	12.4	—
	212,832	145,152	—	51,180	68.2	—	24.0	—	35.2
Oct. 19	188,551	132,457	16,062	—	70.2	8.5	—	12.1	—
	226,322	150,142	—	49,907	66.3	—	22.0	—	33.2
Nov. 16	221,523	152,863	16,731	—	69.0	7.5	—	10.9	—
	176,014	113,854	—	34,850	64 7	—	19.8	—	30.6
Dec. 16	166,286	112,946	14,124	—	67.9	8.5	—	12.5	—
	204,592	138,802	—	50,730	67.8	—	24.8	—	36 5

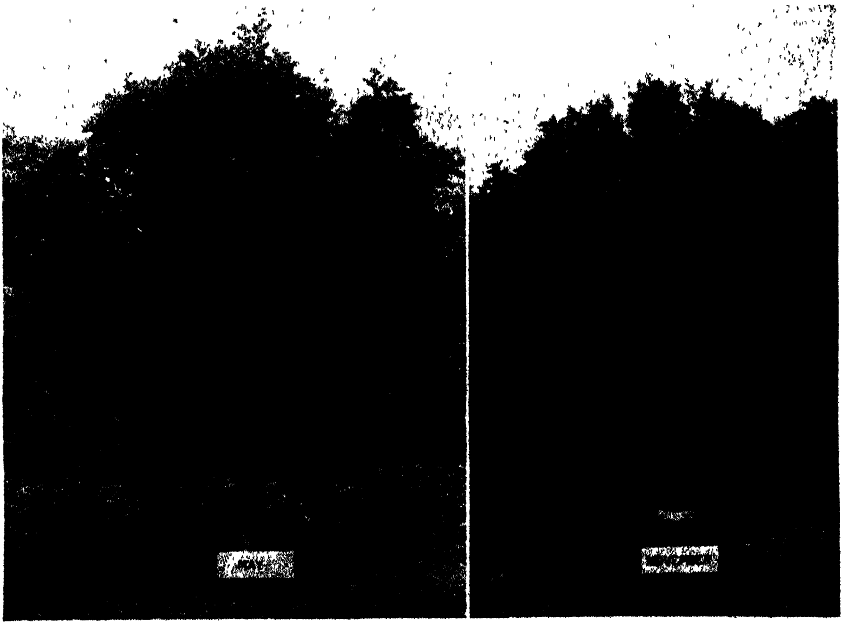

Fig. 1. Difference in rate of top regeneration of spring and autumn pruned Valencia orange trees. Pictures taken one year after pruning.

during the year. Trees pruned between April and July made the most rapid recovery. Actually, considering the two-year period, the high and low points were June and November respectively. In the first year the trees pruned in April and May made the most growth. This was in part due to the fact that they put out new shoots shortly after they were pruned; however, it was mainly due to the new growth made in the spring just before they were dug. The differences in size of spring and autumn pruned trees one year after pruning are shown in Fig. 1.

These data also indicate, as reported previously (3) that citrus trees pruned as severely as these produce more new top growth the second year than they do the first year after pruning.

While the differences in rate of recovery in relation to time of treatment obtained in this experiment are considerable and are believed to be significant, they are smaller than we had anticipated. Had the results of our study of the response of citrus trees to varying degrees of severity of pruning, which indicated that the rate of top regeneration is inversely proportional to the severity of pruning (3), been available when this experiment was initiated the pruning treatment employed would have been much less severe. It seems almost certain that the more rapid rate of recovery associated with lighter pruning would have accentuated the differences due to time of treatment.

Summary and Conclusion

A study of the rate of top regeneration of 24 ten-year-old Valencia orange trees following severe pruning at monthly intervals throughout the year seems to justify the following conclusion: That rate of recovery is most rapid in trees pruned in late spring and early summer (April, May and June) and least rapid in trees pruned in autumn (September, October and November).

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The Effect of Removing the Center Tops of Mature Jonathan Trees on the Arsenical Spray Deposit[1]

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THE need for better spray coverage in the tops of mature trees has long been demonstrated by pest control records, as well as actual residue findings (1, 2, 3, 4). Extra "top-off" sprays (5) have been recommended as a remedy for this situation, which has been further aggravated by the fact that a larger number of codling moth eggs are deposited in the tops as compared with the bottom areas of the trees (6).

In May, 1942, an examination was made of the spray coverage in the tops of mature Jonathan trees in five spray plots at Lafayette. These trees had been given the first cover by an experienced sprayman using a spray gun and 450 pounds pressure. About one-third of a total of 20 gallons per tree had been applied from the inside out with special emphasis on top coverage. Nevertheless a tree by tree examination disclosed a spotted and apparently inadequate spray coverage in the tops of the trees. There seemed to be only two alternatives that might remedy this situation (a) the application of a special top-off spray, and (b) to open up the center tops of these trees as much as possible by pruning. The second method was followed and from four to eight branches, which formed a "canopy" over the center top of each tree, were removed in an average of 17 minutes per tree. This made it possible to do a much improved spray job on these trees at the time of the second, third and fourth cover sprays.

After the fourth cover spray had been completed, fruit samples were taken from the tops of pruned trees and also from an adjacent row of unpruned Jonathan trees of the same age located in the same series of plots that had received the same spray treatments. All trees sampled were sprayed on the same days with equal gallonage and amounts of lead arsenate but otherwise the spray mixtures were different in each of the five plots studied. This resulted in a considerable variation in arsenical deposit as between plots but did not affect the study of spray residue deposits in top and bottom areas of the pruned and unpruned trees, which is the point being considered in this manuscript.

The arsenical residue loads per pound of fruit are shown in Table I. Note the definite increase in spray coverage on the samples from the tops of the pruned trees as compared with samples from the trees in which the tops had not been opened up by a few pruning cuts. Nearly twice as much arsenical load was present on the lower part of the trees as in the unpruned tops of the same trees. This is similar to data for top and bottom coverage published in the past (2, 3). The 1942 data seem to indicate that a small amount of pruning to completely open up at least a small area in the center top of mature apple trees will improve the spray coverage in the tops of the trees and this should result in better control of both codling moth and apple scab.

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[1] Journal Paper No. 78, Purdue University Agricultural Experiment Station.

TABLE I—RESULTS OF RESIDUE ANALYSES MADE ON APPLE SAMPLES TAKEN FROM THE TOPS OF PRUNED AND UNPRUNED JONATHAN TREES AFTER THE FOURTH COVER SPRAY

Plot	Part of Tree Sampled	Grams As_2O_3 Per Pound Fruit*	Pruning
7	Bottom Top Top	0.237 0.258 0.164	None in 1942 Center top removed No top pruning
6	Bottom Top Top	0.380 0.351 0.234	None in 1942 Center top removed No top pruning
5	Bottom Top Top	0.235 0.235 0.117	None in 1942 Center top removed No top pruning
4	Bottom Top Top	0.263 0.234 0.188	None in 1942 Center top removed No top pruning
2	Bottom Top Top	0.259 0.242 0.135	None in 1942 Center top removed No top pruning

*Fifty apple samples were collected. Two separate arsenic determinations were made and the average shown in this table.

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Spray Coverage of Apple Trees as Affected by Different Methods of Application[1]

By Albert L. Weber and Harry C. McLean, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

AT THE request of several New Jersey apple growers we renewed our studies of spray coverage which were started in 1934 (1). The present studies were made in order to determine coverage where spray materials were applied by the newest methods. As a result of these studies, the New Jersey apple growers have modified their methods of spray application whenever changes were found desirable.

Various methods of applying the spray materials were used by the different growers. The data presented in this paper were obtained mainly during the season of 1942. These data are representative of many samples taken immediately after at least four spray applications in each orchard studied. All spraying was done by the individual grower, who used recommended spray mixtures.

Chemical analyses were made mainly on leaf samples taken from various parts of the tree immediately after a spray application, and also on samples of apples from which the stem ends were removed. Apple samples were taken from the same locations on the tree as the leaf samples. Spray coverage was determined as previously reported (2). All results are given in micrograms of arsenic trioxide per square inch of surface.

Sprayers used by some growers are known as speed sprayers and contain up to 103 nozzles at the head end. The pump pressure in this outfit is between 45 and 50 pounds. The spray material as it comes from the nozzles is forced into the tree by a current of air formed by an airplane-type propeller.

In Table I data are presented showing the coverage on similar sizes and types of trees in the same orchard sprayed by the same men with a speed sprayer and with equipment which utilized a 6-nozzle broom from the ground and a similar nozzle broom from a tower on a portable spray rig, the pump pressure being 400 pounds. The speed sprayer apparently deposits spray in the form of a very fine mist as compared to the coarser particles deposited by spray guns and brooms. Although more material was deposited per square inch of leaf and apple surface on the trees sprayed with the speed sprayer than on the trees sprayed with 6-nozzle brooms, the same amount of spray material per tree was used in both cases. This is explained by the fact that more spray material ran off the trees sprayed with the brooms, and therefore the wastage of spray materials was greater. It should be pointed out that our data show the speed sprayer to give a fairly even coverage only if used properly (see Table V). It should also be pointed out here that the human factor is much more important in obtaining a good coverage with a single-nozzle spray gun or any of the spray brooms than with a sprayer that has fixed nozzles. Because of greater

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[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Spray Residue Investigations.

TABLE I—SPRAY COVERAGE OF APPLE TREES IN THE SAME ORCHARD WITH A SPEED SPRAYER AND WITH A HIGH-PRESSURE PORTABLE SPRAYER ON THE FOURTH COVER SPRAY APPLICATION UTILIZING TWO SIX-NOZZLE BROOMS

Location on Tree	Speed Sprayer		High Pressure Equipment, 6-Nozzle Brooms	
	Micrograms As_2O_3 Per Sq In of Leaf	Micrograms As_2O_3 Per Sq In of Apple Surface	Micrograms As_2O_3 Per Sq In of Leaf	Micrograms As_2O_3 Per Sq In of Apple Surface
Inside top	91.0	16.5	98.0	14.9
Outside top	119.0	22.5	126.0	17.2
Inside bottom	140.0	32.7	84.0	24.2
Outside bottom	175.0	41.3	154.0	34.6

run off, other methods of applying the spray (single-nozzle spray gun, 6-nozzle and 16-nozzle brooms) were found to give adequate coverage only when a large amount of material was used.

In Table II data are presented showing the coverage of trees sprayed with vertical nozzle brooms, using a pump pressure of 400 pounds. Three brooms having 6 to 8 nozzles each are attached to a stationary vertical boom. The brooms are placed on this boom at different heights, vertically to the ground. All the nozzles can be turned up or down at the same time with one lever. The results showed that although the spray material was applied under high pressure, it did not have sufficient penetrating power into the interior of the tree.

TABLE II—SPRAY COVERAGE OF APPLE TREES SPRAYED WITH STATIONARY SETS OF HIGH PRESSURE VERTICAL NOZZLE BROOMS ON SECOND COVER SPRAY APPLICATION

Type of Tree	Location on Tree	Micrograms As_2O_3 Per Sq In of Leaf
Open foliage	Top	84.0
Open foliage	Inside bottom	63.0
Open foliage	Outside bottom	91.0
Dense foliage	Top	70.0
Dense foliage	Inside bottom	49.0
Dense foliage	Outside bottom	91.0

To obtain a better coverage on the top and inside of the tree by this method of spraying, one grower built a side platform on his spray rig near the ground and had an extra man use a 4-nozzle broom from this platform to spray the inside of the trees. The results are presented in Table III.

Results of the chemical analyses, which show the penetrating power and evenness of spray coverage effected by different methods of application, are given in Table IV. The criterion of penetrating power was the amount of As_2O_8 found on the samples of leaves from two trees of the same size, in the same orchard, sprayed at the same time with the same sprayer, one tree having an open structure and sparse foliage, the other tree having a structure of a denser nature and heavy foliage.

TABLE III—SPRAY COVERAGE OF APPLE TREES WITH DENSE FOLIAGE SPRAYED WITH MODIFIED HIGH-PRESSURE VERTICAL NOZZLE BROOM SPRAYER (FOURTH COVER SPRAY APPLICATION)

Location on Tree	Type of Sprayer	
	With Extra Broom	Without Extra Broom
	Micrograms As_2O_3 Per Sq In of Leaf	
Top	134.0	112.0
Inside bottom	140.0	84.0
Outside bottom	140.0	154.0

These trees are designated as "open foliage" and "dense foliage" respectively.

We found that certain growers were driving the tractors hauling

TABLE IV—SPRAY COVERAGE OF APPLE TREES OBTAINED BY DIFFERENT METHODS OF APPLICATION (AFTER FOURTH COVER SPRAY)

Type of Tree	Location on Tree	Micrograms As_2O_3 Per Sq In of Leaf	Micrograms As_2O_3 Per Sq In of Apple
1. Speed Sprayer—Proper Tractor Speed			
Dense foliage	Top	98.0	22.0
Dense foliage	Inside bottom	112.0	25.8
Dense foliage	Outside bottom	140.0	32.8
Open foliage	Top	98.0	23.2
Open foliage	Inside bottom	126.0	32.8
Open foliage	Outside bottom	140.0	36.4
2. High-Pressure Portable Sprayer Utilizing Two 6-Nozzle Brooms			
Dense foliage	Top	126.0	17.2
Dense foliage	Inside bottom	84.0	24.2
Dense foliage	Outside bottom	154.0	34.6
Open foliage	Top	119.0	16.6
Open foliage	Inside bottom	98.0	24.2
Open foliage	Outside bottom	154.0	32.7
3. High-Pressure Portable Sprayer with a 16-Nozzle Horizontal Spray Broom Attached to Top of Spray Tank			
Dense foliage	Top	112.0	18.7
Dense foliage	Inside bottom	98.0	13.5
Dense foliage	Outside bottom	161.0	21.9
Open foliage	Top	140.0	27.8
Open foliage	Inside bottom	126.0	23.2
Open foliage	Outside bottom	231.0	36.1
4. High-Pressure Vertical Nozzle Equipment Brooms Attached to Vertical Boom			
Dense foliage	Top	106.0	41.5
Dense foliage	Inside bottom	70.0	38.7
Dense foliage	Outside bottom	154.0	53.0
Open foliage	Top	114.0	23.2
Open foliage	Inside bottom	91.0	27.0
Open foliage	Outside bottom	140.0	34.8
5. High-Pressure Stationary Sprayer Using Single-Nozzle Spray Gun from Ground			
Dense foliage	Top	245.0	56.5
Dense foliage	Inside bottom	210.0	76.1
Dense foliage	Outside bottom	266.0	89.0
Open foliage	Top	231.0	50.9
Open foliage	Inside bottom	231.0	60.0
Open foliage	Outside bottom	252.0	70.9

their spray equipment at too fast a speed for good coverage. The speed of the tractor must not be too great if the tops of large trees are to be properly covered with spray material by the speed sprayer. This is brought out by the data in Table V, which were obtained after the second cover spray. The trees were the same size, measuring 30 feet high and 36 feet wide.

TABLE V—INFLUENCE OF TRACTOR SPEED ON SPRAY COVERAGE WITH THE SPEED SPRAYER (SECOND COVER SPRAY APPLICATION)

Speed of Tractor	Location on Tree	Micrograms As_2O_3 Per Sq In of Leaf
Very fast	Top	31.0
	Inside bottom	31.0
	Outside bottom	56.0
Fast	Top	49.0
	Inside bottom	77.0
	Outside bottom	126.0
Slow	Top	84.0
	Inside bottom	84.0
	Outside bottom	119.0

PRACTICAL IMPLICATIONS OF RESULTS

From a survey of the growers who have used different methods of applying sprays during the past season and from the chemical analyses of the samples taken, it can be stated that the so-called speed sprayer does an efficient job if used properly and reduces labor considerably. One grower, for example, in 1942 was able to spray his orchard with the help of three men and one sprayer in 4 days, whereas in 1941 with a conventional type sprayer, he needed seven men and two spray rigs to cover his orchard completely in 6 days provided there were no adverse winds. Such winds did not prevent efficient coverage with the speed sprayer. Several other growers have had similar experiences.

With this newer method of applying spray materials the human factor is eliminated to a large extent.

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Further Evidence on the Effect of Time and Severity of Pruning on the Rate of Top Regeneration of Citrus Trees

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IN previous papers we have reported on the effects of severity of pruning (1) and time of pruning (2) on the rate of top regeneration of citrus trees. The present paper reports the results of a trial designed to compare the effects of differential pruning in the autumn with those previously reported for similar treatments in the spring (1).

MATERIALS AND METHODS

The trees used for this study were not quite as uniform in size as those which provided the material for the studies already reported. The rootstocks presumably were identical throughout since they were part of the same lot of carefully selected nucellar seedlings of a sweet orange clone which furnished the rootstocks for most of the trees in the orchard. However the scion of each tree used for the present study represented a different clonal strain of the variety concerned instead of all the trees of each variety constituting a single clone as in the previous studies. This undoubtedly accounted for most of the relatively small differences in size, which are shown by the data. The trees were the same age as those previously used; all were planted in May, 1929.

For this trial nine trees were selected, three each of Valencia orange, navel orange and grapefruit. One tree of each lot was lightly pruned, essentially as illustrated and described under A in the previous paper (1). This pruning involved removing all parts less than 1 centimeter in diameter and some thinning of branches. The prunings, including the leaves, amounted to about 50 per cent of the weight of the above-ground parts of the tree. The other two trees of each lot were moderately and heavily pruned as illustrated and described under B and C of the earlier paper. These treatments involved the removal of from two-thirds to four-fifths of the weight of the top.

The pruning was done on September 26 and 27, 1940, a record being kept of the fresh weight of the material removed. Each tree was permitted to regenerate a new top unrestricted until mid-August, 1942 at which time all the trees were cut off at soil level and determinations made of the fresh weights of the original parts of the tree and of the new growth. Leaves and shoots of a sufficiently large aliquot to make possible a reliable calculation of the relative amounts of each, were separated and fresh weights determined.

DATA AND DISCUSSION

All the data relating to fresh weights, and calculated values showing the relationship between new top growth, weight of prunings and weight of the tree above-ground are presented in Table I.

Weight above-ground was chosen as a basis for calculation rather

TABLE I—EFFECTS OF THREE DEGREES OF SEVERITY OF AUTUMN PRUNING ON THE RATE OF TOP REGENERATION OF VALENCIA AND NAVEL ORANGE AND GRAPEFRUIT TREES

Variety or Species	Tree	Prunings		New Top			Leaves		Crop
	Weight Before Pruning (Gms)	Weight (Gms)	Per Cent of Total*	Weight (Gms)	Per Cent of		Weight (Gms)	Per Cent of Total*	At Time of Collection (Gms)
					Total*	Prunings			
				Light					
Valencia. .	182,546	88,907	49	64,560	35	73	45,975	25	16,800
Grapefruit	209,350	97,070	46	73,740	35	76	37,297	18	22,500
Navel. . . .	129,277	73,937	57	65,499	51	89	28,575	22	3,900
				Medium					
Valencia .	179,872	133,812	74	46,660	26	35	29,132	16	458
Grapefruit	183,722	127,462	70	75,500	41	59	42,637	23	4,845
Navel . . .	146,542	116,122	79	40,020	27	34	24,057	16	4,205
				Heavy					
Valencia. .	193,542	156,492	81	39,440	20	25	24,716	13	25
Grapefruit	131,598	97,978	75	39,700	30	40	21,808	16	24
Navel. . .	132,674	103,874	78	29,540	22	28	18,305	14	1,500

*Above ground.

than total tree weight because it appears to be equally reliable for purposes of comparison, provided the trees are similar in size (1) and because it is much quicker and cheaper to obtain than total tree weight, which involves excavation of the root system. Weight above-ground before pruning was obtained by adding the weight of the prunings to the weight of the top, less new growth at the time of collection. We believe that the trees used were sufficiently similar in size to make possible a reliable comparison with those previously used.

The data presented in Table I indicate, as 'do those for the spring pruned trees at the end of a 2-year period (1), that the rate of top regeneration is inversely proportional to the severity of pruning. Lightly pruned trees regenerate a new top more rapidly than do heavily pruned trees.

The data shown in Table II support the conclusion previously presented (2) that spring pruned trees regenerate new tops more rapidly than do autumn pruned trees. On this point the evidence already presented [(2) Table II] is somewhat more convincing than that presented here. The trees used for the previous study were all of the same clone and were all pruned during the same 12 month period. They were, therefore, in so far as it is possible in a study of this nature each subjected to the same environmental conditions for a comparable length of time. In the present study the time interval was the same for the spring and autumn pruned trees; however, as previously stated, they were not all of the same clone, nor were they pruned during the same calendar year. The spring pruned trees were pruned in February 1939 and were therefore subjected to 1939 and 1940 growing seasons; the autumn pruned trees were pruned in September 1940 and were subjected to 1941 and 1942 growing seasons. If growth conditions were less favorable during the second period than they were during the first,

TABLE II—EFFECT OF TIME OF PRUNING ON THE RATE OF TOP REGENERATION DURING A TWO YEAR PERIOD AFTER PRUNING (NEW GROWTH EXPRESSED AS A PERCENTAGE OF PRUNINGS)

Pruning Treatment	Spring 1939*	Autumn 1940
Valencia		
Light	88	73
Medium	59	35
Heavy	43	25
Grapefruit		
Light	105	76
Medium	80	59
Heavy	56	40
Navel		
Light	84	89
Medium	—	34
Heavy	30	28

*Data from column 10 Table I of reference (1).

one might expect that the spring pruned trees would regenerate new tops more rapidly than autumn pruned trees.

In order to determine whether one growth period was more favorable than the other we have calculated the number of hours during each period when the atmospheric temperature was above 55 degrees F which we consider to be the approximate threshold temperature for growth of citrus (3, 4). These data are presented in Table III. They indicate that the spring pruned trees were subjected to about 1000 more hours of temperature above 55 degrees during the 2-year period after pruning than were the autumn pruned trees. That this may in part account for the differences in growth is probable. However we consider it less important as a determining factor than the characteristic cyclic growth of citrus trees. At Los Angeles the growth cycles occur in February-March, July-August and October-November. Normally more new growth is produced during the spring flush than during either of the other two.

TABLE III—NUMBER OF HOURS OF ATMOSPHERIC TEMPERATURE ABOVE 55 DEGREES F BETWEEN FEBRUARY 1939 AND AUGUST 1942

1939		1940		1941		1942	Total
Feb–Aug	Aug–Feb	Feb–Aug	Aug–Feb	Feb–Aug	Aug–Feb	Feb–Aug	
3,338	3,128	3,517	2,865 ⟵(Spring pruned trees)				12,848
	(Autumn pruned trees)⟶		2,865	3,253	2,698	2,962	11,778

Apparently pruning, even though severe, does not materially disrupt the growth cycles. Spring pruned trees begin new top growth within 2 or 3 weeks after pruning. New growth on autumn pruned trees is usually much less abundant during the first 3 to 6 months after pruning even though temperature conditions are apparently more favorable for growth.

That temperature is not the dominant factor seems to be indicated by the response of the trees pruned at monthly intervals throughout a calendar year (2). Considering a 2 year period after pruning, most new growth was made by the June pruned tree (29.9 per cent) and the least by the November pruned tree (19.8 per cent), yet the amount of heat, measured as total number of hours during which atmospheric temperature was above 55 degrees F, was essentially the same for these two trees — 12828 and 12560 hours respectively. On the other hand, the December tree, which received 12509, and the March tree, which received 13350 hours of temperature above 55 degrees F, both produced about 24 per cent of new growth.

As in the case of the spring pruned trees, all the trees produced some fruit the second year after pruning. The amount of crop at the time of collection was inversely proportional to the severity of pruning. Again the Valencia was slower to resume fruiting than either the navel orange or grapefruit.

SUMMARY AND CONCLUSIONS

This study of top regeneration of autumn pruned citrus trees compared with trees similarly pruned in the spring merely substantiates conclusions stated in previous publications, most important of which are the following: (a) That the rate of top regeneration and resumption of fruiting during a 2-year period following pruning is inversely proportional to the severity of pruning. (b) That autumn pruned trees regenerate new tops more slowly than do spring pruned trees.

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Winter Injury to Trunks of Young Bearing Apple Trees in West Virginia Following a Fall Application of Nitrate of Soda[1]

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THESE observations were made in an orchard of 400 8-year-old apple trees, chiefly of the varieties Golden Delicious and Summer Rambo, but which included smaller numbers of Jonathan and Rome Beauty.

The orchard site lies at an elevation of 2,000 feet above sea level on the summit of Patterson Creek Mountain in Hampshire County, West Virginia, 1,500 feet above the valley floor two miles distant. The north-south summit ridge protects from the prevailing westerly winds nearly all of the trees discussed in this report.

The slope in the block varies from 8 to 35 per cent, averaging about 15 per cent. The air drainage is excellent with the mountain falling off just below the orchard in slopes of 45 to 60 per cent.

The erosion-proof soil is of the Elliber series and the type is a cherty loam. Practically all precipitation drains through the soil profile; the internal drainage is excellent at all times. In spite of the fact that the Elliber is typically a mountain-top soil, adapted chiefly to fruit and forest trees and to pasture, it is surprisingly deep for the topography and cannot be considered a shallow soil in any respect. The soil reaction in this orchard varies from pH 4.4 to 6.5, averaging approximately pH 5. The characteristics of the Elliber series are described more adequately elsewhere (2).

The ground cover consists primarily of a mixture of volunteer native plants, chiefly Canada bluegrass (*Poa compressa*), blueberries (*Vaccinium spp.*) and dewberries (*Rubus spp.*) and secondarily of a wide range of other mountain flora typical of that zone of the Appalachian Region. Only in small isolated areas is there anything approaching a thin sod. The general impression is that of an expanse of gravel with a scanty vegetal cover.

The soil cultivation consists merely of an annual mowing of the higher-growing volunteer vegetation with hand scythes. No attempt is made to stir the soil in any way. About 12 years before the block was set, the trees comprising the deciduous forest were timbered. The growth of subsequent vegetation was controlled by goats.

The apple trees set at 30 feet on the triangular system are small for their age, chiefly because of severe damage inflicted a year or two after planting by the periodical cicada (*Magicicada septendecim*, L.). The extensive injury caused by this insect was practically eliminated in the subsequent pruning, but this action resulted in an extreme degree of

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dwarfing of the trees. Severe fire-blight infections for two successive years, 1940 and 1941, and the consequent pruning for the removal of the blighted wood have stunted the Jonathan and Rome Beauty trees still more but have affected very little the principal varieties, Golden Delicious and Summer Rambo. The trunk diameters vary from 4 to 9 centimeters, averaging about 6 centimeters. The largest trees are of the Summer Rambo variety, followed closely by the Golden Delicious and then by the considerably smaller Jonathan and Rome Beauty. The first light crop was borne in 1941 chiefly by the Summer Rambo and the Golden Delicious trees. All four varieties bloomed heavily and produced good crops in 1942.

The standard West Virginia spray schedule has been applied with an efficient stationary spray plant.

The total precipitation for 1941 was about an inch less than the normal of 37 inches at the Romney station of the United States Department of Commerce, Weather Bureau, 12 miles distant by air line. October was abnormally warm with an average temperature of 4.9 degrees F above normal and with about the usual amount of precipitation. November was 2.9 degrees above normal in temperature and nearly normal in precipitation. December was warm with a positive temperature departure of 4.9 degrees and with normal preciptation. No secondary growth was observed during the 1941 season. Up to the time the nitrate was applied there had been one heavy freeze of 24 degrees F on October 26.

Chilean nitrate of soda was applied under the spread of the branches during the first week in November, 1941, at the rate of ¾ pound per tree. All trees in the block were treated.

After the application of the nitrate no official Weather Bureau temperatures below 14 degrees (December 29) occurred at Romney until early in January, when the thermometer dropped from 31 on the 5th to minima of 6, 0, —6, —3, 10, and —6, which were recorded from the 6th through the 11th; this was by far the coldest period of the winter. A thermometer in the orchard is said to have registered a low of —11 during the same period.

About a week after this cold period, the pruning crew reached this part of the orchard and presently observed severe cracking of the bark on the trunks of many individual trees. These longitudinal cracks were on the due southern side only of the trunks of about 20 per cent of the Golden Delicious, Fig. 1, and of approximately 10 per cent of the Summer Rambo, Fig. 2, Jonathan, and Rome Beauty trees. Usually there was only one long crack, although sometimes there were two or more with their ends arranged in horizontal echelon, as Fig. 1 shows. The injury began 5 to 10 centimeters above the ground line and extended in some instances for more than one meter up the trunk, frequently reaching above the first scaffold branch and occasionally extending above the second or the third, Fig. 1. No crotch injury was observed except as the crack originating lower in the trunk passed the point of attachment of a branch as the wound extended up the trunk, Fig. 1; no damage was apparent to any other part of the tree.

Not only was the bark cracked longitudinally but it was loosened radially for one-fourth to one-third of the trunk circumference. The separated bark was usually alive at the time of the first observation by the writers on April 23, 1942; new tissues were being laid down both on the outer and on the inner surfaces of the bark with nearly all of such trees. In a few instances, the loose bark was mostly dead, while in other cases it was partly alive and partly dead. Islands of live cambium still adhering to the sapwood were observed on some individuals.

As the nitrate had been applied to every tree in the block, there was none which was not fall-fertilized, so that direct comparisons of the same varieties in the same area with and without autumnal applications of nitrogen were not possible. The only comparable group of approximately even-aged trees which had not received a similar fall application of nitrogen was a block of 300 of the Richared sport of Delicious. These were on a closely similar site with an identical exposure at practically the same elevation and on the same soil series and type. There were absolutely no signs of injury on the trunks of these Richared trees. The parent variety, Red Delicious, is not resistant to

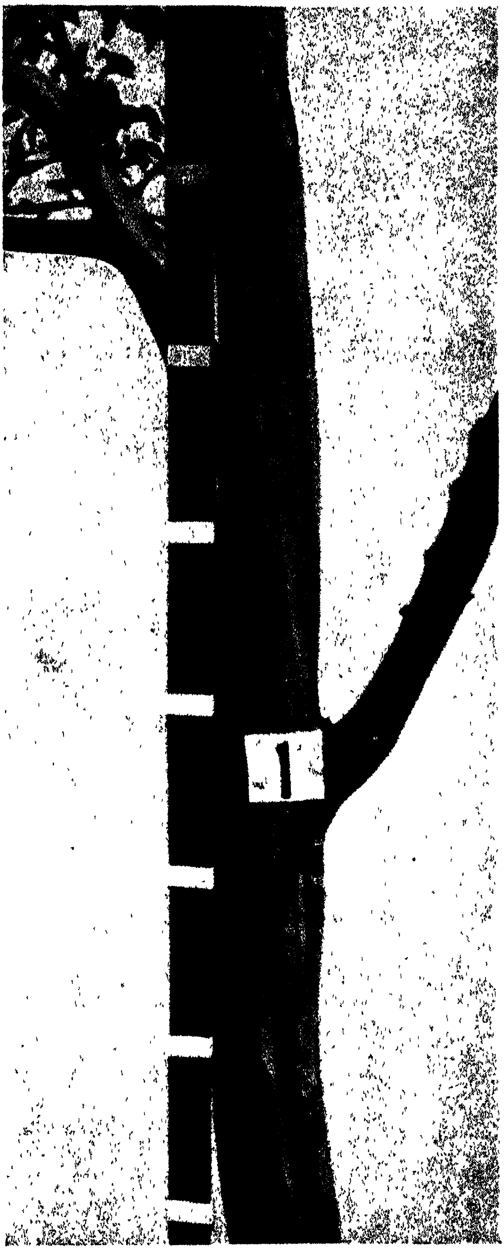

Fig. 1. Winter injury to trunk of 8-year-old apple tree, variety Golden Delicious, winter of 1941–42; West Virginia Appalachians. White bands on meter stick are at 10 centimeter intervals.

this type of injury associated with immaturity (1).

While this circumstantial evidence cannot be regarded as establishing conclusive proof that this case of severe winter injury is traceable either wholly or in part to the fall application of the nitrogen, there is a justifiable suspicion that there was some connection. The nitrogen may have served merely to upset a little further any already extant physiological conditions predisposing the trees to a lowered resistance to such injury.

This belief is heightened by the fact that in these same orchards there have been other instances in which an identical type of winter injury followed fall applications of some nitrogen carrier. The foreman who has been with the orchards since their beginning about 20 years ago asserted that in all but one of the approximately half dozen winters of severe injury in the history of the orchards, nitrogen had been applied in the autumn preceding the winter directly causing the damage. In that single exception, the winter injury to Maiden Blush trees was of an entirely different type—which involved the killing of much of the tops—a type not associated with immatur-

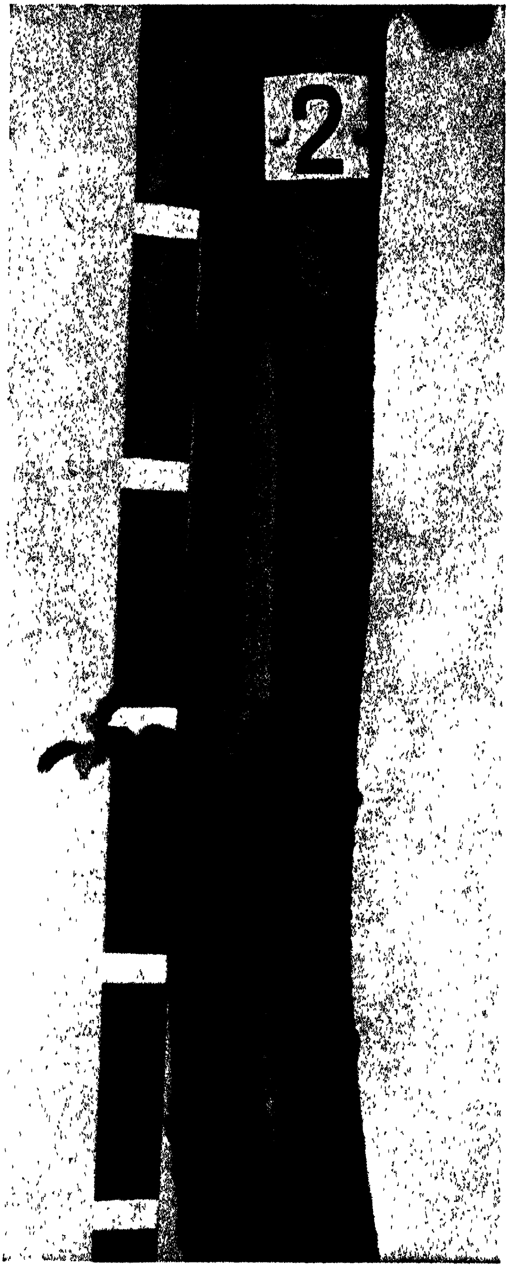

FIG. 2. Winter injury to trunk of 8-year-old apple tree, variety Summer Rambo, winter of 1941–42; West Virginia Appalachians. White bands on meter stick are at 10 centimeter intervals.

ity of the tissues. The fall application of nitrogen has not been a practice followed habitually in the orchard.

It is true that most of the commercial apples produced in West Virginia come from orchards on very different soils lying at lower elevations, and with somewhat different climatic environments. In spite of these variations, there still must remain an element of concern and uncertainty regarding the wisdom of recommending the general use of fall applications of nitrogen to apple trees, even as far south as northern West Virginia. It is admitted that in most years and in most orchards, there would likely be no reason to regret later the tendering of such advice to the grower. However, what has occurred once may happen again quite unexpectedly.

No particular point should be made of the use of Chilean nitrate of soda in this block of apple trees; any other nitrogen carrier might have preconditioned the physiology of the trees for the development of either more or less winter injury. We do stress the fact that there still is much to be learned about the physiological effects of fall applications of nitrogen to fruit trees.

This report merely adds to previous indications such as those similar instances described by Rawlings and Potter (4) and by Tingley *et al.* (5) that under unknown conditions something may tend to go wrong at certain times when nitrogen is applied to orchards in the autumn, and that the nitrogen may have some influence predisposing the trees to injury.

Modlibowska and Field (3) have reported the occurrence of a similar type of winter injury at the East Malling Research Station; trees of higher vigor, apparently because of a double application of potash, showed much more damage than did those slower growing ones with a single amount.

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A Report of Injury by Cold Weather to Peach Trees in Illinois During the Winter of 1941–42

By DILLON S. BROWN, *University of Illinois, Urbana, Ill.*

TWO types of injury which may be attributed to low temperatures during January were observed on peach trees in Illinois during the 1942 season. In one type the injury was confined to the trunks, usually at or just below the ground line. The trees bloomed and produced foliage. Many died early in the season, shedding both leaves and flowers or fruit, when fruit had been set. Others set fruit and produced a fair amount of foliage but were weak in the production of new shoots and died later. Some trees in this latter group did not show signs of injury, except by a somewhat weakened growth, until harvest time. Many trees, which 10 days before harvest appeared to be uninjured and were carrying a fair crop, lost their leaves and died before the crop could be harvested.

The trunk injury was characterized by the killing of the bark and cambium at or below the ground line. There was no evidence of bark splitting or of a separation of the bark from the wood. The injury extended up into the scaffolds on many of the trees which died early in the season. The injury on trees which died later after setting fruit and producing leaves and a limited shoot growth was usually below ground and could not be detected by cutting into the trunk at or above the ground line. In many instances the injury, especially on trees which died about harvest time, was from 3 to 6 inches below ground. The roots were not injured except as the injury seemed to progress from the affected areas of the trunk.

Most of the orchards where trunk injury occurred were in south-central Illinois, principally in Jefferson County. Trees of all ages were affected; those on the upper parts of slopes were the first to die out. The temperatures during the first 10 days of January averaged 16 to 20 degrees below normal; 6 of the 10 days in southern Illinois were below zero. The lowest official temperature recorded at Mount Vernon, in Jefferson County, was —10 degrees F. Unofficial minimum temperatures noted in the vicinity of orchards where trunk injury occurred were as low as —18 degrees F on January 8 and 10.

This particular type of trunk or collar injury, in which the effects are apparent early in the summer immediately following the winter in which the injury occurs, has not been reported as frequently as the type in which the injury has become most obvious one or more years after the damage was done. The injury to peaches in 1942 was similar to that observed in southern Illinois in 1924 following low temperatures in the winter of 1923–24 (2).

The other type of injury observed was more generally distributed throughout the peach areas of the state. This injury was confined to the tops, mostly on 1941 wood and in the crotches of branches and shoots. Vigorous trees, 3 to 5 years old, were most often affected; the injury on older trees was confined to the most vigorous shoots or branches. The lowest official temperatures reported during the first

10 days of January from typical areas in which injury to the tops occurred were —8 degrees at Carbondale and —9 degrees at Anna.

Trees showing the injury had an excellent foliage early in the season, produced vigorous shoots, and, in many instances, set a fair to good crop of fruit. The injury was evident first early in July, when rolled and reddened leaves, which occasionally had necrotic margins, were observed on the affected shoots. By harvest many shoots and some branches were dead. Exudation of a brownish gum appeared in crotches and on the bark of injured shoots and limbs. The wood was brittle and broke readily, especially where gum appeared. The shoots which died were characterized by injury to the bark in the area just below the terminals of the 1941 wood; in effect, the shoots were girdled at these points. The shoots increased in diameter below, but not in, the injured areas; it could not be determined whether the cambium had been injured directly by the cold or had died later. However, the 1941 terminal buds were not injured, and they produced very vigorous shoots before the effect of the injury caused the death of the shoots. The injury apparently affected the cambial region principally in the areas immediately below the terminal buds or just immediately above the lateral buds on the 1941 wood. The cambium on either side of injured areas was characterized by the presence of a clear, sticky, somewhat stringy, gum-like substance.

The leaves of the new shoots, produced from terminal buds just below which girdling had occurred, developed an appearance characteristic of the leaves of trees affected with potassium deficiency or a combined potassium and phosphorus deficiency. It seems probable that the injury did not impair the translocation of water and solutes early in the season, since vigorous shoots were produced by the 1941 terminal buds. However, since new conducting tissues were not produced and since the gums from the injured areas ultimately impaired translocation in the wood, the shoots above the girdled areas, in time, actually may have become deficient in some of the elements. Therefore, it is not surprising that the leaves on such shoots became similar in appearance to those on potassium and phosphorus deficient trees.

Injured trees were examined by H. W. Anderson, who found no evidence that either a primary or secondary infection with a fungus, bacterium, or virus was involved, either at the time the injury was first observed or later in the season.

The characteristics of the injury to the bark, which was also accompanied in many instances by marginal necrosis of the leaves, are very similar to those of the injury attributed to arsenical sprays by Childers and Mitchell (1). However, the injury observed in Illinois was found sometimes in orchards where no arsenicals were used. Also, many of the growers in whose orchards injury was observed used arsenical dusts, which are not so apt to cause injury as are sprays. The 1942 season in Illinois was wet, so undoubtedly conditions were favorable for arsenical injury. It is possible that the injury observed may have been aggravated in many instances by arsenicals; however, it is believed that the injury to the tops of peach trees in Illinois was primarily the result of low temperatures in January. The facts that the injury was observed where no arsenicals were used and that it was predominately on 1941 and older wood lead to that conclusion. The only evidences of injury on 1942 wood were at the bases of some new shoots where the injury seemed to have progressed into the new wood from an injured area back of the 1941 terminal.

Probably both types of injury, that on the trunks and that in the tops, were the result of the inability of insufficiently matured tissues to withstand low temperatures. The immaturity of the tissues was doubtless associated with summer drought in 1941, followed by heavy rains in October and warm weather in November and December. Adequate rain during the spring and early summer of 1942, which kept the soil wet and in some areas on the verge of saturation, may have contributed to the effects of the January cold.

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Southern Pear Breeding[1]

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AMERICAN fruit growers and nurserymen have made either accidental or controlled crosses of *Pyrus serotina* and *P. communis* for about a century. Le Conte is one of the early hybrids and originated about 1846. Cox (1) published an excellent account of these early hybrids, many of which have been forgotten or are no longer in common cultivation. It is interesting to note that Kieffer, Garber, and Pineapple are the best-known varieties that are one-half *P. serotina*. Many thousands of crosses of this type must have been made, and a few thousand more are not likely to produce better varieties than Kieffer. A survey of the Southeastern States made in 1942 indicates that pears of this type are widely grown except in the warmest parts of Florida and Texas. *Serotina* hybrid pears appear to be the most widely grown pomaceous fruit. Their distribution suggests that they are reasonably well adapted to this region. The trees are often grown under more or less neglect. Perhaps we could call it "neglect culture". The fruit is sold for canning and preserving. All reports received mentioned its poor quality. Many correspondents objected to their early blossoming and to the fact that the fruit matures over a short period of time. Most growers and pomologists report that the trees have little more than survival resistance to fire blight. They blight from time to time but continue to live and produce some fruit.

PLAN

This was the situation in the southeastern part of the United States when the pear-breeding project was begun at the Tennessee Agricultural Experiment Station in 1925. Breeding stock was assembled and work was started in 1932 according to the plan shown in Fig. 1. Backcrossing offered a method of correcting the failings of these F_1 hybrids noted above, provided sufficient fire-blight resistance could be retained. Lantz (3), Hsiong and Hildebrand (2), Wellington (4), and others have published some inheritance data which are useful in selecting parents, but in some crosses the number of progenies was small.

TECHNIQUE

There is little that is new in the technique used in this project. Bartlett, Seckel, and most European varieties blossom from a month to 6 weeks after Pineapple and similar hybrids. Pollen was gathered from dwarf trees or from forced branches in a greenhouse and stored in desiccators containing 45 per cent sulfuric acid and held at a temperature of about 45 degrees F. All blossoms were emasculated in a bud stage even when the variety had been found self-sterile. Large trees were tented, usually with a heavy grade of tobacco cloth. A cage

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[1] Records previous to 1941 were kept by J. A. McClintock and H. L. Fackler. E. M. Henry 1932 to 1935, Arthur Meyer 1938–1939, and D. M. Bailey 1940–1941 assisted with this project.

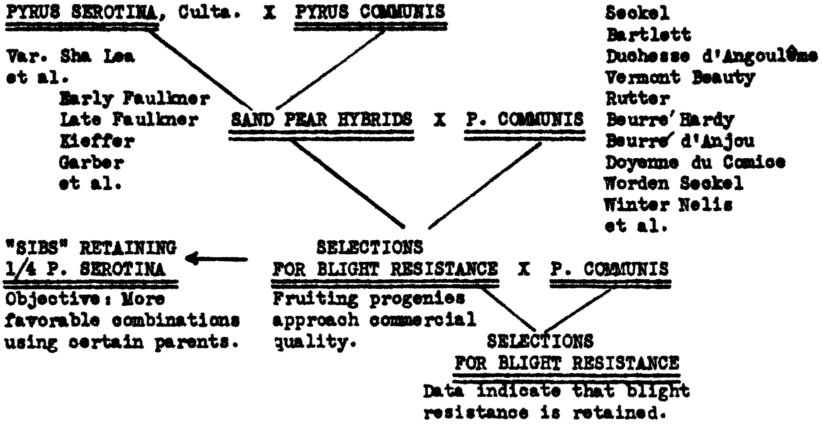

FIG. 1. Tennessee plan for pear breeding.

with hotbed sash for sides and tobacco cloth for top gave some protection from late frosts and other adverse weather, as well as excluding insects. Seeds of early-maturing varieties ripen in late July under Tennessee conditions and were stored dry until time to start the after-ripening process. Various disinfectants were used, but a fresh bleaching-powder solution gave fair control, with no appreciable injury to the seeds. A special veneer dirt band 3 inches by 3 inches and 8 inches long was very satisfactory for handling the young seedlings. Three inoculations were made each season during the second and third years in the nursery row, natural inoculum and a budding technique being used. This method of inoculation is very severe, but efficient. A number of additional seedlings usually developed fire blight when they blossomed. Seedlings that failed to develop fire blight after six inoculations were top-worked into older trees for further trial, fruiting, and observations. Several tree arrangements were used in the orchard, but four trees per hole and holes 20 feet by 20 feet were found most convenient.

INHERITANCE DATA ON FIRE BLIGHT RESISTANCE

A small number of species crosses between oriental and European pears were made in 1932 and 1933. The oriental species included *Pyrus serrulata, P. calleryana,* and *P. ussuriensis.* Vermont Beauty, Seckel, Bartlett, Worden Seckel, and Clapp varieties represented the European pear parent. Out of 156 progenies, 111 developed fire blight and 28.8 per cent have not blighted up to the present time. None of the fruit from these crosses appears promising.

Table I presents data on the fire-blight susceptibility of 1586 progenies that contain one-fourth *Pyrus serotina.* About half of this population is 8 or more years old. Several hundred of the seedlings have fruited, and 51.5 per cent have not developed fire blight to date — which is a much higher percentage than in the species-cross population mentioned above. Kieffer, Garber, and local varieties were used as the source of *P. serotina.* The quality of fruit produced does not aver-

TABLE I—PEAR PROGENIES WITH ONE-FOURTH *Pyrus Serotina*

Cross	Total Number of Progenies	Number of Progenies Developing Fire Blight	Date When Crossed
♀ ♂			
Late Faulkner × Duchess d'Angouleme	391	237	1934
Worden Seckel × Kieffer	308	221	1934
Seckel × Late Faulkner	305	121	1936 and 1938
Seckel × Early Faulkner	147	37	1935 and 1938
Seckel × Garber	116	23	1934 and 1935
Garber × Duchess d'Angouleme	79	19	1939
Worden Seckel × Garber	51	24	1933, 1935, 1938
Bartlett × Early Faulkner	38	15	1938
Bartlett × Garber	23	15	1933 and 1937
R4T2 × Vermont Beauty	32	15	1931
Late Faulkner × Vermont Beauty	26	18	1931 and 1934
Garber × Beurré d'Anjou	25	12	1937 and 1938
Early Faulkner × Bartlett	22	7	1934
Garber × Doyenné du Comice	12	2	1938
Garber × Vermont Beauty	11	3	1937
	1,586	769	51.5 per cent not blighting

age high, but a number of seedlings have been isolated that have rated good or better commercially. Time of blossoming averaged later than Pineapple and Kieffer. Grit cells are usually not conspicuous. Flavor is rarely better than medium. Seckel, Vermont Beauty, and Worden Seckel progenies tend to make weak growth and average high in leafspot susceptibility. A few seedlings have been isolated which appear to approach the ideal in vegetative characters, but are small-fruited. Several of these have been used in further crosses, which will be discussed under Defoliation.

Table II presents progeny data of fire-blight susceptibility for 710 seedlings containing one-eighth *Pyrus serotina*. This population has had six inoculations, but is only 3 years old, and an appreciable number should be expected to develop blight in the orchard from blossom infection. None have fruited. The data to date suggest that this population will average about as resistant as that listed in Table I.

INHERITANCE DATA ON DEFOLIATION

Defoliation of European varieties of pears in late summer is very striking under southern conditions. This may be due partly to vari-

TABLE II—PEAR PROGENIES WITH ONE-EIGHTH *Pyrus Serotina*

Cross	Total Number of Progenies	Number of Progenies Developing Fire Blight	Date When Crossed
♀ ♂			
Tenn. Seedling 34S377 × Duchess d'Angouleme	375	70	1939
Tenn. Seedling 34S77 × Duchess d'Angouleme	150	88	1939
Tenn. Seedling 31S97 × Beurré d'Anjou	64	24	1939
Tenn. Seedling 31S208 × Bartlett	43	7	1939
Tenn. Seedling 31S97 × Duchess d'Angouleme	31	7	1939
Tenn. Seedling 31S107 × Beurré d'Anjou	27	7	1939
Tenn. Seedling 31S98 × Beurré Hardy	20	9	1939
	710	212	70.1 per cent not blighting

ations in nutrition, but is at least accompanied by heavy leaf-spot infection. Hybrid seedlings vary greatly in susceptibility to this disease. Duchesse d'Angouleme progenies average less susceptible than those from Seckel. Data on defoliation are presented in Table III for the progenies of several Tennessee seedlings. Note that Garber x Duchesse d'Angouleme offsprings defoliate heavily. The Tennessee seedlings used in the first three crosses in the table are small-fruited forms; those of the last three combinations are large-fruited. The genetic explanation of these small-fruited and healthy seedlings is not clear. They have from two to four carpel cells, compared with five for large-fruited varieties. They might involve chromosome changes, but they hybridize readily with the usual varieties. Some of the writer's associates have suggested that they could be caused by an accumulation of recessive genes. Their breeding behavior supports this theory. Both parents in all cases were large-fruited and such offsprings were only a small percentage of the progeny population involved.

TABLE III—DEFOLIATION OF PEAR PROGENIES

Cross	Number of Progenies Considered	Percentage of Defoliation Sep 17, 1941*
♀ ♂		
Tenn. Seedling 34S377 × Duchess d'Angouleme	343	40.9
Tenn. Seedling 34S77 × Duchess d'Angouleme	58	45.3
Tenn. Seedling 34S377 × Tenn. Seedling (Duhamel-Kieffer)	47	14.0
Garber × Duchesse d'Angouleme	66	92.5
Tenn. Seedling 31S97 × Beurré d'Anjou	52	65.4
Tenn. Seedling 31S208 × Bartlett	40	69.1
Tenn. Seedling 31S97 × Duchess d'Angouleme	24	86.5
	630	57.6 average

*All progenies unsprayed and the second season in nursery row.

The above is just a progress report. The material produced up to the present time is promising. Fire-blight resistance appears to have been retained in many of the back crosses. Some of the selections fruited seem to possess better characters than Kieffer and Garber. Several thousand seedling selections are yet to fruit. Further hybridizing is planned. It is hoped that varieties will be isolated that may serve a considerable part of the eastern United States and ripen from July to midwinter or later.

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Longevity of Pistache Pollen Under Various Conditions of Storage

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REVIEW of available foreign literature on the pistache nut reveals little specific information on its pollen other than the preference noted by Falci (4) for hybrid males over those of *Pistacia vera* L., because of the abundance of pollen produced and Savastano's (14) report that pollens of *P. vera, P. Terebinthus* L. and their hybrids retained their viability for from 15 to 20 days in the laboratory at temperatures varying from 20 to 25 degrees C but in Petri dishes held out-of-doors lost their viability in 2 days in the shade and in 2 hours in direct sunlight. In pollination studies on a collection of Pistacia species and varieties, started in 1936, at the Division of Plant Exploration and Introduction's garden at Chico, California (20) dichogamy was extensive enough in the material available to preclude certain desired pollinations without the use of stored pollen. Furthermore, in view of Savastano's statement, understanding of the various factors influencing the effectiveness of pistache pollens is of fundamental importance in evaluating males from foreign sources.

Reports of studies on pollen of anemophilous plants (1, 2, 3, 5, 7, 9, 10, 16, 17, 22, 23) indicate considerable differences in longevity and in temperature and humidity requirements, suggesting that in plants of diverse origin climatic adaptations outweigh the requirements for wind pollination. In general, pollen longevity seems to have been influenced more by variations in humidity than by those in temperature. Reporting on the interrelation of temperature and humidity in studies carried on through 1937 and 1938 with 19 varieties, representing four genera, King and Hesse (7) found the one pistache pollen tested giving maximum germination (30.2 per cent) at the end of 550 days of storage at 36 degrees F, and relative humidity of 25 per cent, conditions which were optimal for many of the pollens they tested and it was concluded that although a favorable temperature is necessary to obtain maximum germination after a long storage period, favorable relative humidity appeared to be the more important factor of the two. Several workers have reported on behavior of pollen in vacuum. Kellerman (6) found that citrus pollen dried over concentrated sulphuric acid and sealed in glass vacuum tubes at about 5 millimeters pressure remained viable for more than 2 months. Knowlton (8) compared Antirrhinum pollen stored at 0 degrees C and 10 degrees C in sealed glass tubes at 100 millimeters pressure and in normal pressure and found pollen remaining viable longer at atmospheric pressure. Wilcox (21) reported apple pollen as living three times as long in a vacuum as in a desiccator.

MATERIALS AND METHODS

In the studies now reported, pollens of five species of pistacia, *Pistacia vera* L. Nos. 3, 4, 9 and 23[1]; *P. atlantica* Desf. Nos. 16 and 32; *P. chinensis* Bunge Nos. 1, 8, and 34; *P. integerrima* Stewart No. 14; and *P. Terebinthus* L. No. 15[1], representing a wide range of origins were investigated. Selection of individual staminates of each species was based on tree growth, flowering, pollen yield and viability. Pollen No. 23 is a staminate grown from seed introduced from Aleppo, Syria, in appearance suggesting a hybrid of *P. vera* x *P. Terebinthus*. This particular male is outstanding for its vigor, the large size and quantity of its flowers and the abundance of pollen produced. Pollen No. 4, Peters, is a named seedling selection. The other pollens used are unnamed seedling selections. In the field tests of pollen viability two pistillate varieties of *P. vera, Bronte* and *Sfax,* were used in the controlled pollinations.

Preliminary studies indicated that the optimum time to collect pollen to obtain maximum viability was during the earlier stages of pollen dehiscence. Large numbers of staminate clusters (500 to 600) were collected at random over the entire tree just prior to general anthesis. Each pollen sample was dehisced in a separate, closed, air-conditioned room at 22 to 24 degrees C. Pollen was dehisced in volumes of 100 milliliters to 200 milliliters on screen trays over sheets of Kraft paper. The individual pollens were then screened free of foreign material through 100-mesh copper screen. Each sample was thoroughly mixed by this method, ensuring a fully randomized sample representative of each staminate tree. The viability was then checked and each sample was apportioned at random to each respective experiment and placed under storage conditions.

In certain instances larger quantities of pollen were held in screw cap glass bottles at a storage temperature of 0 degrees C for short intervals before they were placed under the experimental conditions. Previous tests indicated that this procedure did not materially reduce pollen viability. Testing of all pollens after a uniform number of days in storage was not feasible.

The culture media used for determining pollen viability by artificial germination were granulated cane sugar solutions (10 to 20 per cent) and sugar-agar gelatin. In 1939 after considerable testing, a 14 per cent sugar-agar gelatin solid medium similar to that reported by Newcomer (11) was adopted, as it proved to be more satisfactory than the liquid medium. Pollen was cultured by the hanging drop method in the liquid medium. In the solid medium technique, random pollen samples were disposed in four separate areas, or quadrants, of a slide thinly smeared with a film of sugar-agar-gelatin. The slides were then placed in sealed moist chambers for germination. Incubation was at the predetermined optimum temperatures of 26 to 28 degrees C for 24 hours in thermostatically controlled ovens. Germination percentages were determined by estimating the percentage of germination in each of the four random samples and selecting the highest percentage obtained as more nearly representing the maximum viability of each pollen tested. All estimates were made by one worker who made exact counts during each testing interval as a check on the relative accuracy of the estimates.

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[1] Probable hybrid.

The lower temperatures of the storage conditions were obtained in an electric refrigerator. All the experiments on storage were conducted within an air-conditioned laboratory which tended to make the room conditions more nearly uniform and to overcome the wide seasonal variations experienced in this region.

The relative humidities reported for the 1938 test were maintained over anhydrous calcium chloride for zero per cent and over a saturated solution of calcium chloride for the relative humidity of 32.3 per cent. The 10 per cent relative humidity was obtained over a saturated solution of zinc chloride. In the 1939 and 1940 tests, the relative humidities were secured over aqueous mixtures of sulfuric acid based on data reported by Stevens (17). All relative humidities were calculated at 20 degrees C, and no adjustments were made for the variations in humidity due to fluctuations of temperature, or to opening the desiccators at the times of checking viability. The humidity chambers employed throughout this work were 6-inch Scheibler glass desiccators with ground glass covers, sealed with white petrolatum.

The reduced pressure reported in the 1938 tests were obtained by the use of a fast-acting rotary vacuum pump. Side-opening test tubes, exhausted to the desired pressure of 36 millimeters and sealed off securely were used as the reduced pressure chambers. The pressure was determined by means of a mercury manometer at the time the test started and when the tubes were opened. During the 1939 and 1940 tests of temperature and reduced pressure 1-pint thermos bottles were used. Those kept at 125 millimeters pressure were rubber stoppered, provided with glass stopcocks, and securely sealed. A slow acting vacuum pump was used on the thermos bottles to prevent the collapse of the fragile glass thermos element by the sudden reduction of pressure. The thermos bottles at atmospheric pressure of 760 millimeters were closed with cork stoppers. The millimeters of pressure reported were calculated from an industrial type vacuum guage. No attempt was made to determine or control the relative humidity within the thermos bottles.

Gelatin capsules (No. 000) were used as the pollen containers in 1938 and 1939 tests as suggested by Traub (19). In the 1940 tests cotton-stoppered shell vials were used because of their convenience and ease of loading. Larger quantities of pollen were tested in 2- and 4-ounce, screw-capped, glass jars at —2 degrees C in volumes sufficient for field pollinations. No attempt was made to control the humidity within the capped jars; but at the time of sealing, the relative humidity of the room ranged between 30 and 40 per cent. The relative humidity of the air within the refrigerator, as measured by a corrected hygrothermograph, varied from 24 to 30 per cent. Controlled pollinations in the field were carried on in canvas bags with transparent windows following technique developed for work with pine at the Institute of Forest Genetics (15).

RESULTS

Pollen No. 23 was used in 1938 in a preliminary study to determine the storage conditions favorable to retention of pollen viability. The differences in viability of No. 23 pollen at the end of 63 days of storage under various conditions of relative humidity at each of four temperatures (Table I) illustrate the importance of proper temperature and humidity during the storage of pistache pollen. In the three atmospheres maintained, maximum germination was secured at 0 degree C, and with 32.3 per cent humidity. At all humidities germination decreased with rise in temperature. Pollen in a vacuum at 36 millimeters at 0 degree C retained its viability satisfactorily, but not significantly better than that held at 0 degree C and 32 to 38 per cent relative humidity. Regardless of the maintenance of reduced pressure or a favorable relative humidity, pollen after 63 days of storage at 19 degrees C and 24 degrees C was apparently dead.

TABLE I—GERMINATION OF POLLEN NO. 23 AFTER SIXTY-THREE DAYS OF STORAGE (1938)*

Storage Conditions		Germination (Per Cent) of Pollen Stored at Mean Temperature of			
Relative Humidity (Per Cent)	Pressure (Mm)	0 Degrees C	6 Degrees C	19 Degrees C	24 Degrees C
0	760	5	2	0	0
10	760	8	3	0	0
32.3	760	25	5	0	0
Uncontrolled	36	35	10	0	0

*Initial germination was 37 per cent. When tested after 94 days of storage at these conditions all of the pollen was dead.

During 1939 and 1940 the influence of relative humidity on the viability of five species of pollen when stored at —1 degree C was studied. To determine whether or not the various species of pistache were consistent in their response, pollen from the same trees was tested in two seasons, with the exception that pollen No. 34 was substituted for pollen No. 1 in 1940. Table II indicates the conditions of the experiment and the response of the various pollens tested. Germination tests of fresh pollen and for periods prior to 78 days of storage during the 1939 tests are omitted because conducted in sucrose solution. Those reported were made on sugar-agar gelatin. Despite the wide differences shown in the two years in several cases, though the pollens used were taken from the same trees, for which no explanation is advanced at this point, the rather uniformly consistent effects of humidity are striking. Rarely did the extreme humidities, particularly the lowest, conduce to germination as good as that secured after storage at intermediate humidities. Between the three intermediate humidities no absolute choice can be made, but the lower portion of the range, that is, 10.5 per cent and 21.5 per cent seem to have

TABLE II—LONGEVITY OF POLLEN OF FIVE PISTACIA SPECIES STORED AT —1 DEGREE C AND VARIOUS RELATIVE HUMIDITIES

Days Stored	1939					1940				
	Germination of Pollen Stored in Relative Humidity of					Germination of Pollen Stored in Relative Humidity of				
	1.5 Per Cent	10.5 Per Cent	21.5 Per Cent	33.5 Per Cent	38.0 Per Cent	1.5 Per Cent	10.5 Per Cent	21.5 Per Cent	33.5 Per Cent	38.0 Per Cent
Pistacia vera Number 4 (Peters)										
0	—	—	—	—	—	55	55	55	55	55
9	—	—	—	—	—	20	25	1	0	T
78	0	5	25	20	2	0	0	2	0	0
103	0	10	5	10	5	—	—	—	—	—
139	—	—	—	—	—	0	T	1	T	T
334	—	—	—	—	—	0	0	0	0	0
722	0	T*	T	T	0	0	0	0	0	0
999	0	0	0	0	0	—	—	—	—	—
Pistacia vera Number 23†										
0	—	—	—	—	—	55	55	55	55	55
9	—	—	—	—	—	45	T	30	10	35
78	50	60	60	70	30	0	15	15	25	20
112	30	70	40	80	50	—	—	—	—	—
139	—	—	—	—	—	T	25	20	60	65
344	—	—	—	—	—	0	10	40	25	20
621	—	—	—	—	—	0	3	1	0	0
731	3	55	40	10	5	0	T	T	T	0
858	—	—	—	—	—	0	T	T	T	0
1,008	T	10	5	3	0	—	—	—	—	—
1,133	0	10	2	T	T	—	—	—	—	—
Pistacia atlantica Number 16										
0	—	—	—	—	—	50	50	50	50	50
31	—	—	—	—	—	45	40	20	15	5
87	5	10	20	15	10	—	—	—	—	—
100	—	—	—	—	—	10	65	30	45	20
112	2	5	10	10	5	—	—	—	—	—
161	—	—	—	—	—	5	20	35	45	60
366	—	—	—	—	—	1	8	30	15	15
643	—	—	—	—	—	T	5	2	0	0
731	0	2	1	0	0	0	8	3	1	T
1,008	0	0	0	0	0	—	—	—	—	—
Pistacia chinensis Number 34 (1940)										
0	—	—	—	—	—	95	95	95	95	95
33	—	—	—	—	—	T	10	30	2	20
87	1	2	10	5	0	—	—	—	—	—
102	—	—	—	—	—	0	20	15	5	2
112	0	2	3	3	1	—	—	—	—	—
163	—	—	—	—	—	0	10	2	5	5
368	—	—	—	—	—	0	10	10	T	T
645	—	—	—	—	—	0	2	0	0	0
731	0	T	T	0	0	0	T	0	0	0
882	—	–	—	—	—	0	T	0	0	0
1,008	0	0	0	0	0	—	—	—	—	—
Pistacia integerrima Number 14										
0	—	—	—	—	—	15	15	15	15	15
33	—	—	—	—	—	0	0	0	0	0
87	0	0	20	T	0	—	—	—	—	—
112	0	0	15	0	0	0	0	0	0	0
163	—	—	—	—	—	0	T	0	0	0
368	—	—	—	—	—	0	0	0	0	0
731	0	0	5	0	0	—	—	—	—	—
1,008	0	0	0	0	0	—	—	—	—	—
1,133	0	0	T	0	0	—	—	—	—	—
1,245	0	0	T	0	0	—	—	—	—	—
Pistacia Terebinthus† *Number 15*										
0	—	—	—	—	—	65	65	65	65	65
33	—	—	—	—	—	T	T	T	0	T
87	0	2	T	T	T	—	—	—	—	—
102	0	1	T	0	0	0	0	0	0	T
163	—	—	—	—	—	0	T	T	T	T
368	—	—	—	—	—	0	0	T	T	0
645	—	—	—	—	—	0	0	0	0	0
731	0	0	0	0	0	0	0	0	0	0

*T = Less than 1 per cent germination.

†Probable hybrid.

produced rather better results than 33.5 per cent. If a definite percentage must be singled out, 21.5 per cent seems most likely to be fairly suitable.

The influence of relative humidities of 1.5, 10.5, 21.5, 29.5, 33.0, 49.0, 76.7 and 89.9 per cent was tested in 1940 at room temperature of 22 to 26 degrees C. The same pollens and procedures were used in this test as were used in the preceding one on the influence of relative humidities at —1 degree C. The duration of viability under these conditions was short; however, some germination of pollens Nos. 16 and 23 was obtained after 16 days of storage at the humidity levels from 21.5 to 49.0 per cent. Pollen No. 23 was considerably stronger than pollen No. 16. Even these pollens failed to germinate after 40 days of storage at room temperature regardless of the humidity maintained.

These tests show, as did that reported in Table I, that temperature cannot be disregarded as a factor in pollen storage; they also indicate that storage at extremes of humidity is fatal, even in a short period. This view appears to substantiate results obtained by Olmo (12) who found that with grape pollen stored at —12 degrees C, 28 per cent humidity was more favorable than 54 per cent.

The results of tests made to measure the effects of temperature and reduced pressure on pollens stored in thermos bottles are presented in Table III. The lowest temperature (—9.7 degrees C) was generally the most favorable for the retention of viability. Olmo (12) found that pollen longevity of three varieties of *Vitis vinifera* L. was greater at —12 degrees C than at 2 and 10 degrees C. Regardless of medium, temperature and pressure employed, all pollens tested in 1939 had lost germinability in 87 days, except No. 23, which had not decreased in this respect after 112 days.

In most cases reduced pressure at 125 millimeters appeared to be harmful to pistache pollen viability. Exceptions were noted in the responses of *Pistacia atlantica* No. 16, in 1939 and of *P. vera,* No. 4, in 1940, in which somewhat better results were obtained at reduced pressure than at atmospheric pressure.

Differences under these various conditions of storage in the two years were not consistent or important, except that the lower temperature seemed to extend the period of viability to some extent.

Reviewing all the tests reported, it is clear that the evidence does not warrant implicit reliance on any one temperature or any one humidity for storage of pistache pollen. The vagaries and inconsistencies reported, which will not appear unusual to those who have conducted similar studies, may be interpreted to signify that successful storage may be secured in a fairly extensive range of temperatures and humidities, but that extremes of humidity and high temperatures should be avoided. The evidence seems ample to justify statements of differences in storage life of pollen between individual trees and inferentially between species.

Question has been raised whether pollens which germinate in tests after being stored for a long period are capable of fertilizing the ovules of their species when used in pollination work. Sandsten (13) and

TABLE III—THE INFLUENCE OF TEMPERATURE AND PRESSURE UPON POLLEN STORED IN THERMOS BOTTLES

Pollen Number	Days Stored	1939 Tests*				1940 Tests†								
		Normal Pressure (760 Mm)		Reduced Pressure (125 Mm)		Days Stored	Normal Pressure (760 Mm)				Reduced Pressure (125 Mm)			
		Mean Temperature		Mean Temperature			Mean Temperature				Mean Temperature			
		–9.7 Degrees C	–1 Degree C	–9.7 Degrees C	–1 Degree C		–9.7 Degrees C	–1 Degree C	8.3 Degrees C	25 Degrees C	–9.7 Degrees C	–1 Degree C	8.3 Degrees C	25 Degrees C
Pistacia vera														
4	0	20	20	20	20	0	55	55	55	55	55	55	55	55
	15	15	0	7	1	21	10	0	0	0	35	30	T	T
	29	4	T	2	0	78	0	0	0	0	0	0	0	0
	43	T	0	T	T	141	0	0	0	0	0	0	0	0
	78†	0	0	0	0	—	—	—	—	—	—	—	—	—
23	0	8	8	8	8	0	55	55	55	55	55	55	55	55
	24	40	20	8	20	21	65	1	0	0	4	0	0	0
	38	50	40	3	4	78	0	0	0	0	0	0	0	0
	52	40	40	T	2	141	0	0	0	0	0	0	0	0
	87†	40	10	0	0	—	—	—	—	—	—	—	—	—
	112†	50	60	0	0	—	—	—	—	—	—	—	—	—
	731†	0	0	—	—	—	—	—	—	—	—	—	—	—
Pistacia atlantica														
16	0	5	5	5	5	0	50	50	50	50	50	50	50	50
	24	20	T	5	5	43	35	0	0	0	0	0	0	0
	38	T	T	15	T	100	0	0	0	0	0	0	0	0
	52	T	0	3	T	163	0	0	0	0	0	0	0	0
	87†	0	0	0	0	—	—	—	—	—	—	—	—	—
Pistacia chinensis														
1	0	10	10	10	10	0	95	95	95	95	95	95	95	95
34	24	4	T	2	T	45	T	0	0	0	0	0	0	0
	38	1	T	T	0	102	0	0	0	0	0	0	0	0
	52	T	0	0	0	165	0	0	0	0	0	0	0	0
	87†	0	0	0	0	—	—	—	—	—	—	—	—	—
Pistacia integerrima														
14	0	2	2	2	2	0	15	15	15	15	15	15	15	15
	24	20	10	1	0	45	0	0	0	0	0	0	0	0
	38	2	2	T	0	102	0	0	0	0	0	0	0	0
	52	T	T	T	0	165	0	0	0	0	0	0	0	0
	87†	0	0	0	0	—	—	—	—	—	—	—	—	—
Pistacia terebinthus														
15	0	4	4	4	4	0	65	65	65	65	65	65	65	65
	24	5	0	T	1	45	0	0	0	0	0	0	0	0
	38	1	0	T	0	102	2	0	0	0	0	0	0	0
	52	T	0	0	0	165	0	0	0	0	0	0	0	0
	87†	0	0	0	0	—	—	—	—	—	—	—	—	—

*In liquid media.
†In sugar-agar gelatin.
T = Less than 1 per cent germination.

Knowlton (8) have stated that pollen may be able to germinate yet not function.

As a check on reliability of the pollen germination percentages secured in this work, pollinations using stored pollens of various ages were made on blossoms of two varieties of pistache during the 1940 and 1941 flowering period. Performance of 1- and 2-year-old species pollen stored in tightly lidded screw capped glass bottles in a household refrigerator at a temperature of —2 degrees C (relative humidity of refrigerator 24 to 30 per cent) is shown in Table IV. No fertilized ovules were secured from 1-year-old pollen of *Pistacia chinensis*, *P. vera* No. 9 and *P. Terebinthus*, which showed complete loss of viability in germination tests made at time of application. With the exception of the *P. Terebinthus* pollen used in 1940, fertilized ovules were secured from all pollens which showed any sign of life in germination tests. It is interesting to note that some filled nuts were secured from the use of both 1- and 2-year-old pollen which gave only a trace of germination. Olmo (12) found grape pollens with 1 to 3 per cent germination practically always failing to produce a set, but those showing a germination of as little as 6 to 8 per cent sometimes producing sets that approached or exceeded normal. Aldrich and Crawford (1) secured good sets with date pollen stored from one season to the next in tightly lidded fruit jars in a household refrigerator at about 40 degrees F.

TABLE IV—SET PRODUCED ON BRONTE AND SFAX WITH POLLEN STORED AT —2 DEGREES C

Species	Pollen Number	Days Stored	Germination When Applied (Per Cent)	Average Number of Filled Nuts Per Cluster*		
				Bronte (T–1)	Bronte (T–4)	Sfax
Season of 1940						
Pistacia chinensis	8	380	0	0.00	0.00	—
Pistacia Terebinthus	15	385	T	0.00	0.00	—
Pistacia vera	23	383	5	6.74	14.05	—
Pistacia vera	23	5	40	8.35	17.88	—
Open pollinated	—	—	—	16.78	22.93	—
Season of 1941						
Pistacia Terebinthus	15	746	0	—	—	—
Pistacia Terebinthus	15	389	0	—	—	—
Pistacia vera	9	370	0	—	—	—
Pistacia vera	3	734	T	—	—	3.00
Pistacia integerrima	14	393	T	1.93	—	3.24
Pistacia atlantica	16	394	5	2.78	—	6.20
Pistacia atlantica	32	393	8	—	4.80†	—
Pistacia vera	23	744	T	0.00	0.20†	0.06
Pistacia vera	23	359	25	3.50	4.43†	5.42
Pistacia vera	23	16	55	4.72	7.85†	13.57
Open pollinated	—	—	—	8.64	8.00	11.65

*Five bags of approximately four clusters used for each pollen.
T = Less than 1 per cent germination.
†Only three bags used.

In the spring of 1941, pollinations were made (Table V) on a Bronte tree, using the 2-year-old pollen of No. 23 previously stored in capsules at each of the relative humidities used in Table II. Germination percentages secured from pollen stored at 10.5 and 21.5 per cent relative humidity compare favorably with that of fresh pollen which gave a germination of 55 per cent in 1940 and 1941.

TABLE V—SET PRODUCED ON BRONTE WITH FRESH AND WITH STORED POLLEN

Relative Humidity of Storage (Per Cent)	Days Stored	Germination When Applied (Per Cent)	Filled Nuts Per Cluster* (Mean)
1.5	745	3	1.17
10.5	745	55	8.08
21.5	745	40	6.64
33.5	745	10	2.56
38.0	745	5	2.67
—	16	55	7.85
Open pollinated	—	—	8.00

*Three bags with approximately four clusters per bag used for each pollen.

The sets secured seem in general to parallel the results of the germination tests and to confirm the reliability of such tests as indices of the actual fertilizing value of pollen.

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Some Outstanding Seedling Progenies of Tung

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MOST of the tung acreage in the United States has been planted to seedling trees. When the United States Field Laboratories for Tung Investigations were established in 1938, the selection and breeding of tung varieties became one of the important projects initiated. In most tung orchards there is a very wide variation in tree type, height of head, ratio of pistillate to staminate flowers, productiveness, size and shape of fruit, oil content of the fruit, thickness of hull, and resistance to low temperatures. It was thought that selection and breeding might lead to the production of varieties having the most desirable characters.

In the fall of 1938 selections were made throughout the tung region of the United States, most of the trees in the larger bearing orchards being observed. Yield was the first character noted and nothing less than a high yielding tree was selected. Yield was considered not only for the present season but for the past season as well, the latter being indicated by the fruit stems remaining on the tree. A tree that bore fruit in 1937 was given special consideration as a spring frost that year killed the flowers on many trees. The fruit was observed for size, thickness of hull, and degree of filling of nuts. In considering time of ripening of the fruit an early ripening fruit is preferable as it can be picked from the ground before leaf fall. This enables the grower to prepare the soil for seeding a winter cover crop early.

The type of tree was noted with preference being given to a spreading tree having a medium height of head and a strong leader. A tree with numerous vigorous terminals and good foliage is preferable as these not only indicate vigor but the terminals are important as a source of asexual propagating material.

After a tree had been selected and the necessary data taken, a sample of more than 100 of its fruits was collected at random and stored in the laboratory. Each tree selected was given a letter (for the State in which it was growing, as L for Louisiana, and M for Mississippi), and a number for the purpose of identification. A portion of the fruits in each case was used for making the necessary studies in the laboratory on their physical characteristics and oil content while the remainder was divided into three lots and planted in February 1939 in nurseries in Louisiana, Mississippi, and Florida. Several thousand seedling trees were grown from this seed.

In January and February 1940, approximately 40,000 of the seedlings grown in Louisiana were transplanted to an orchard near Bush, Louisiana, while another 13,000 from the same nursery were planted in an orchard near Folsom, Louisiana. From 30 to more than 100 of each of several progenies were planted, and a careful record kept of their location in the orchard. These trees were well cared for and made a very rapid growth during the growing season of 1940.

On November 14, 1940, the temperature in these orchards dropped to 17 degrees F. The tung trees were in full leaf. By noon of the 15th the leaves were all on the ground. In a few days it could be readily seen that many of the trees were severely injured, while others showed no sign of injury from the low temperature. Before growth began the following spring a careful check was made of the injury, and all trees that were killed back to the ground were cut off at the ground line. During the growing season of 1941 the growth throughout the orchards was extremely good. The trees that were cut back had grown new trunks and tops, and many were more than 8 feet in height. Those that had resisted the freeze in the fall of 1940 formed many strong laterals with numerous fruit buds.

During the growing season of 1942 it was noted, in the orchard near Folsom, that several progenies from the selections made in 1938 were producing large crops of fruit for trees of their age. In November 1942, after the fruit had fallen to the ground and become fairly dry, yield records were taken on 18 of the progenies in this orchard. An attempt was made to select some of the better progenies as well as some of the poorest. Yield was taken for every tree in each progeny.

The data in Table I show that seedlings of the selection L–51 produced an average of 9.43 pounds of fruit per tree with a coefficient of variability of 73. The 50 trees in this progeny were very uniform in size and appearance. The yield ranged from 0.6 pounds to 28.8 pounds per tree.

TABLE I—YIELD RECORD OF SEEDLING PROGENIES OF A NUMBER OF SELECTIONS

Selection	Seedlings Used (Number)	Average Yield Per Tree (Pounds)	Coefficient of Variability (Per Cent)
L-51	50	9.43	73
L-46	52	5.93	90
A-16a	30	4.63	73
F-3	47	3.61	91
L-45	49	3.34	85
F-499	53	3.19	74
L-11	81	3.16	65
L-40	30	3.09	78
F-56	39	2.73	96
L-14	32	2.46	120
M-9	60	1.60	111
L-28	110	1.03	201
L-19	54	0.89	186
F-47	46	0.88	195
L-31	50	0.72	210
M-77	31	0.59	195
F-24	64	0.39	341
L-41	31	0.11	200

The next highest yielding seedlings were from the selection L–46, with an average yield of 5.93 pounds per tree with a coefficient of variability of 90. The 52 trees in this progeny were not so uniform as those of L–51, since five of them had been killed back to the ground in the fall of 1940. These yielded from 0.0 to 21.4 pounds per tree.

The third highest yielding seedlings were from the selection A–16a, with an average yield of 4.63 pounds per tree and a coefficient of variability of 73. Five of the 30 seedlings of this progeny had been killed to the ground line in the fall of 1940. The yield ranged from 0.0 to 13.9 pounds per tree.

The lowest yielding progeny recorded in this study was from the selection L–41, with an average yield of 0.11 pounds per tree and a coefficient of variability of 200. Fifteen of the 31 trees in this progeny had been killed to the ground line in the fall of 1940.

One mile from the orchard in which these seedlings are growing there is another orchard also planted to seedlings, which is now about 6 years old. There are 1,154 trees in this orchard, all grown from seed from one tree. The uniformity in size of tree, branching habit and all other general appearances are so striking that in 1941 yield records were taken to determine the uniformity of this character. The total yield was 8,336.4 pounds, or an average of 7.22 pounds per tree, with a coefficient of variability of 83.3.

In collecting the data contained in this study it was noted that many of the progenies closely resembled the female parent. The resemblance was so close in the case of tree shape, and in size and shape of fruit that the parent could be named without first observing the label at the beginning of the tree row. Dickey (1) has pointed out, in a study of seedlings from known female parents, that more than 50 per cent of the seedlings from certain parent trees come very true to type. The study reported here indicates the importance of care in selecting seed to be used in producing trees for the establishment of a commercial orchard. It further indicates the importance of testing seed from a selection before one can be certain that a wise selection has been made. All the seedlings reported upon in this study are from parents that were carefully selected, yet it is very evident that some progenies are much better than others. Some had much greater resistance to cold. These variations in the progenies were to be expected since the blossoms were open-pollinated. The parent trees no doubt differ widely in genetic constitution. Further studies, as these trees become older, will determine whether or not the great differences in yield this season continue.

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The Frequency of Polyembryony in Twenty Varieties of Mango

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BELLING (1) first showed that in the ovule in some mango varieties, the egg-cell has never been observed to divide. Such varieties can, however, produce viable embryos from the innermost cells of the nucellus. Embryos thus derived are from mother tissue only and plants resulting from such embryos have the characters of the mother plant. This means of reproduction is termed nucellar embryony. Within one seed several nucellar embryos often develop. In some varieties, such as Pico, studied by Juliano and Cuervas (2) the fertilized egg cell does develop into an embryo that is usually larger than the accompanying nucellar embryos. In polyembryonic mango seed one embryo can be derived from the fertilized egg cell; all the accompanying embryos must be apogamically derived through nucellar embryony.

Polyembryony is, to a certain extent, therefore, an index to whether a variety reproduces through its seed true to the mother tree. Two cautions should, however, be born in mind when polyembryony is considered as such an index. First, there is the possibility that one of the embryos in the seed has been derived from the fertilized egg cell and is therefore, influenced by the character of the male that yielded the fertilizing pollen. Second, the embryo in some monoembryonic seeds may possibly be of nucellar origin. In such a case single seedlings from one seed could not be distinguished as being of nucellar or fertilized egg-cell origin.

TABLE I—NUMBER AND PERCENTAGE OF 7,880 MANGO SEEDLINGS OF TWENTY VARIETIES THAT WERE (A) POLYEMBRYONIC, (B) SINGLE-STEMMED, UNBRANCHED UNDERGROUND, AND (C) SINGLE-STEMMED, BRANCHED UNDERGROUND

Variety	Total Number	Polyembryonic (Per Cent)	Monoembryonic	
			Unbranched Underground (Per Cent)	Branched Underground (Per Cent)
Alphonse	30	13.33	86.6	0.0
Amini	1,800	11.33	80.0	8.66
Brindabani	120	0.0	95.0	5.00
Bulbulchasm	12	25.0	75.0	0.0
Cambodiana	696	43.96	48.7	7.33
Divine	174	0.0	100.0	0.0
D. B. Alphonse	548	31.20	59.6	9.12
Giraffe	778	51.41	42.6	5.91
Itamaracá	228	9.64	84.6	10.08
Jamshedi	30	6.66	90.0	3.33
Kachmahua	285	1.40	90.5	8.07
Martinique	16	6.25	93.7	0.0
Mulgoa	187	1.12	85.0	3.74
Paheri	105	0.0	93.3	6.66
Philippine	495	9.09	88.6	2.22
Pico	236	1.56	83.0	1.27
Reine Amelie	128	3.12	92.1	4.68
Sandersha	917	2.50	94.6	2.83
Sufaida	13	23.07	69.2	7.69
Totafari	1,082	6.93	88.0	4.99

It is easy to confuse polyembryonic seedlings with those monoembryonic seedlings that branch below the soil surface, as shown in Fig. 1. Only by removing the soil down to the germinated seed and examining the underground portion of the stem can it be determined if a multiple-stemmed seedling is actually from one or from more embryos.

Studies were made of 7,880 mango seedlings of 20 varieties to determine (a) the number that were polyembryonic, (b) the number that were monoembryonic and unbranched underground, and (c) the number that, from the soil surface, appeared to be polyembryonic but in reality were monoembryonic and branched below the soil surface as shown in Fig. 1, B. Any seed producing a seedling have a single stem, branched or unbranched, was considered in this study to be monoembryonic. Table I shows the total number of seedlings examined of each variety, the percentages that were polyembryonic, and those that were monoembryonic, branched, and unbranched, below the ground.

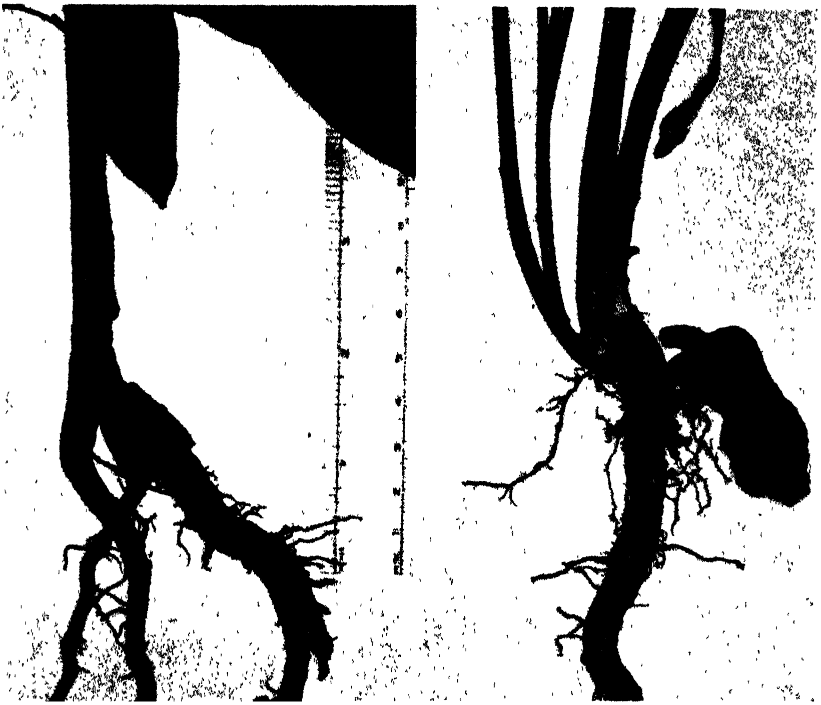

FIG. 1. Seedlings of mango showing more than one stem above ground. A, three stems each from individual embryos in a polyembronic seed. B, four stems all from one single embryo. Without examination of the stems below ground. B, could mistakenly be called polyembronic.

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Inheritance Study of Root Knot Nematode Resistance in Certain Peach Varieties

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HUTCHINS (3) emphasized the importance of the problem of injury to peach trees caused by the root knot nematode, *Heterodera marioni* (Cornu) Goodey, to growers and nurserymen in the Southeast. He described several rootstocks resistant to nematode attack, and mentioned P. I. 63850 (Shalil) and P. I. 61302 as being the most promising rootstocks of those tested. Tufts and Day (4) have reported the resistance to nematode attack of seedlings of several species of fruit plants, including a large number of peach varieties.

During the period 1934 to 1942, open-pollinated seedlings of 151 varieties of peaches were grown at the United States Horticultural Field Laboratory, Fort Valley, Georgia, in soil heavily infested with nematodes. At the end of one growing season, in most tests, the seedlings were dug and their roots examined for the presence of nematode galls. According to the prevalence of galls the infestation of each seedling root was classified as free, trace, moderate, or severe.

Considerable variation existed in the severity of infestation among seedlings of a single variety. Seldom was 100 per cent infestation secured. This variation was probably related to the local nematode population. Since nematode resistance is based on negative evidence, and in view of the small number of seedlings representing some varieties, no attempt has been made in these studies to classify the varieties according to the degree of resistance of their seedlings other than into two groups, resistant and susceptible. Varieties were classed as resistant if galls were rarely or never found on the roots of their seedlings in repeated tests. Although a few of them were not completely immune to attack, they possessed a useful degree of tolerance of nematodes. Varieties were classed as susceptible when a portion of their seedlings had a moderate to severe infestation of nematodes. In our experience, individual seedlings of this group that were apparently resistant, as indicated by freedom from galls in one year, would readily become infested if given a second exposure to attack. Although the susceptible varieties may vary in their degree of resistance to nematodes, from a practical standpoint only those varieties whose seedlings possess a very high degree of resistance are important.

Seedlings of all commercial varieties of peaches included in these tests proved to be susceptible, as shown in Table I. Tennessee Natural seedlings, commonly used as a peach stock in the East, were also quite susceptible to nematodes. Of 2,287 Natural seedlings tested, 90 per cent were infested the first season in the nursery. After a second exposure to nematode attack, 99.9 per cent of these seedlings had galls on their roots. Most of the number-designated kinds of peaches of the Division of Plant Exploration and Introduction likewise proved

TABLE I—GROUPING OF PEACH VARIETIES, CROSSES, AND P. I. NUMBERED SORTS ACCORDING TO RESISTANCE OF THEIR SEEDLINGS TO NEMATODE ATTACK

Group I (Susceptible)

Alton
Arlington 21868
Babcock
Banner
Barnard
Belle of Georgia
Blood Free
Bound Brook Red Leaf
Brackett
Canadian Queen
Captain Ede
Carman
Chairs
Champion
Chili
Chinese Cling
Cumberland
Dawson
Dewey
Dewey × St. John
Early Crawford
Early Elberta
Eclipse
Elberta
Elberta × Newkom
Engle
Eureka
Fay Elberta
Fitzgerald
Frances
Gaume
George IV
Giant Snowball
Globe
Gold Drop
Golden Jubilee
Golden Queen
Halberta
Halehaven
Hale Early
Halford
Hauss
Hiley
Illinois
Indian Blood
Iron Mountain
Japan Giant
J. H. Hale
Johnson
July Elberta
Kalamazoo
Kette
Krummel
Late Crawford
Late Elberta
Lemon Free
Levy
Libbee
Linworth
Lovell
Lukens
Marquette
P. I. 43136
Martha Fern
Mathews
Maxine
Mountain Rose
Muir
Newcomb
New Prolific
Niagara
Oldmixon Free
Opulent
Orange Cling
Pallas
Paloro
Paragon
Peak
Phillips Cling
P. I. 234 (Davidiana)
P. I. 24807
P. I. 29227
P. I. 35201
P. I. 36125
P. I. 40004
P. I. 43124
P. I. 43127
P. I. 43129
P. I. 43133
P. I. 43134
P. I. 43135
P. I. 43139
P. I. 43140
P. I. 43141
P. I. 43142
P. I. 43143
P. I. 43144
P. I. 43146
P. I. 43291
P. I. 45137
P. I. 48508
P. I. 55563
P. I. 55564
P. I. 55813
P. I. 55836
P. I. 65856
P. I. 65977
P. I. 65978
P. I. 68179
Waldo
P. I. 68352
P. I. 68353
P. I. 68354
P. I. 74011
Ray
Rio Oso Gem
Roberta
Rochester
Salberta
Salwey × Libbee
Salwey × Peak
Salwey × Walton
Shippers Late Red
Sims
Slappey
Smock
South Haven
South Tuscan
St. Claire
St. John
Stump
Summer Heath
Sun Glo
Sutter Creek
"Tennessee Natural"
Vedette
Veteran
Viceroy
White Hale
Wilma
Wight

Group II (Resistant)

Bokhara

P. I. 55775 (Yunnan)
P. I. 55776 (Yunnan)
P. I. 55885 (Yunnan)
P. I. 55886 (Yunnan)
P. I. 55888 (Yunnan)
P .I. 61302
P. I. 63850 (Shalil)
P. I. 63852 (Shalil)
P. I. 107838 (Mao Tao)

to be susceptible; a few, however, showed a high degree of resistance.

Twenty-seven seedlings of P. I. 55775, 48 seedlings of P. I. 55886, and 30 seedlings of P. I. 55888, all of the Yunnan group, were entirely free of root knot in nursery tests. Four hundred sixty-three seedlings of P. I. 63850 (Shalil) and 11 seedlings of Bokhara were also entirely resistant. No root knot could be found on any seedlings of the above P. I. numbered sorts and varieties in any year of the tests. Progeny of P. I. 55776 and P. I. 55885 of the Yunnan group, P. I. 63852 of the Shalil group, and P. I. 61302 (a cross of Bolivian Cling and Quetta nectarine) were infested with nematodes to a slight extent, but it is believed that these varieties transmit to their seedlings a high degree of resistance. It would not be valid to state, on the basis of these tests, that they were less resistant than the first-named Yunnan and

Shalil P. I. numbered introductions, because of the variability in the nature of nematode attack.

The resistance of P. I. 55775 and P. I. 55776 has not been reported previously. These introductions were by seed collected from two wild peach seedlings found growing near Puerhfu, Yunnan Province, China. Both of these original seedlings were located within an area of approximately an 8-mile radius from which the other peach introductions of the Yunnan group were found (P. I. 55885, P. I. 55886, and P. I. 55888).

In the group of Mao Tao (Hairy peach, P. I. 107838) seedlings (used in China as a rootstock) three out of seven seedlings were free of root knot under severe test conditions. These three resistant seedlings were given a second exposure to nematode attack, and again proved completely resistant. Three years later, in the orchard, the roots of these trees have become moderately infested with nematodes. Two of these Mao Tao trees have fruited, and their seedlings have been tested for nematode resistance. Seedlings of one tree were 100 per cent resistant, while only 16 per cent of the seedlings of the other tree had any root knot on them. Evidently these Mao Tao trees transmit considerable resistance to nematodes, but as yet they have shown no superiority that would make them preferable to Yunnan as a peach rootstock.

Both Shalil and Yunnan seedlings have been described (3, 4) as possessing unusual vigor. Whether one will be superior to the other for peach trees in the Southeast remains to be seen. Certain difficulties are encountered in the production of Shalil seed in the East and Southeast, however. Shalil trees have a low chilling requirement to break the rest period, and their early blossoming habit makes them susceptible to spring frosts. In colder locations lack of hardiness of wood, bark, and flower buds is a limiting factor. On the other hand, P. I. 55886 (Yunnan) trees are hardier than Shalil trees; and their buds have a chilling requirement similar to Elberta, which has made this variety more dependable in fruit production in Georgia. It therefore offers more promise as a seed source. Blake (1) has reported that P. I. 55776 also is very hardy in wood and bud under New Jersey growing conditions.

The question has often arisen as to the necessity of isolation of orchards to be used for seed production of nematode-resistant stock, so that self-pollination of the flowers would be assured. Conceivably a Shalil hybrid seedling might be less resistant than a selfed seedling. Cross-pollination on P. I. 63850 (Shalil) were made with the susceptible varieties Lemon Free, Gold Drop, and Veteran. Other flowers of the Shalil were self-pollinated. The resulting seed were grown in a heavily nematode-infested location. In a part of the block infested Natural seedlings were planted a foot distant from each Shalil seedling, partly to retain the usefulness of the location as a nematode test block and partly to be certain of the proximity of nematodes to the seedlings under test.

After a full season's growth, an examination of the roots of the Shalil seedlings failed to disclose the presence of a single gall caused by nematodes on 50 self-pollinated seedlings or on 229 hybrid seedlings. The latter included 42 Shalil x Lemon Free seedlings, 89 Shalil x Gold Drop seedlings, and 98 Shalil x Veteran seedlings. Ninety-nine per cent of a group of Natural seedlings tested under the same conditions became infested with nematodes, and of course the Natural seedlings which had been interplanted between part of the Shalil seedlings carried moderate to severe infestations. These results show that the character nematode resistance is dominant in the nursery trees, since Lemon Free, Gold Drop, and Veteran pollen parents carry no factor for resistance. Also P. I. 63850 is homozygous for nematode resistance. Further tests being made on these Shalil hybrids may bring out some differences in the degree of resistance as the trees become older. According to Day and Tufts (2), and in our experience also, a portion of a group of seedlings completely resistant in nursery tests may become moderately infested with nematodes in later years.

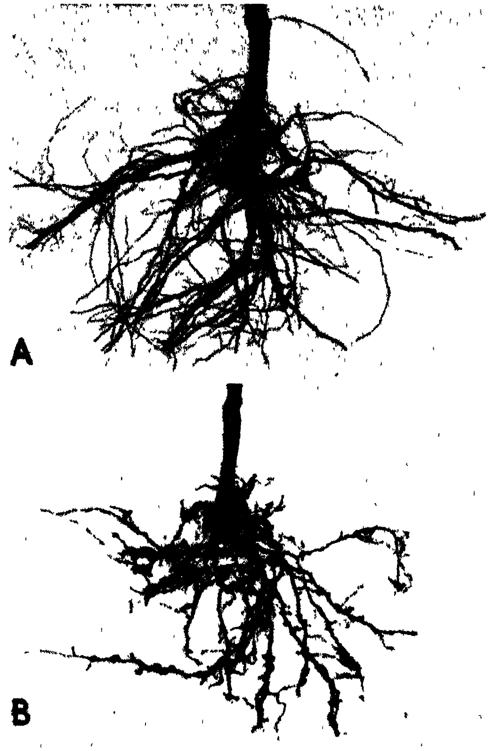

Fig. 1. Showing nematode resistance of Bound Brook Red Leaf (susceptible) x P. I. 55886 (resistant) hybrid (upper) entirely free of root knots, compared with severely infested Mao Tao seedling (lower) grown adjacent to it. Only one Mao Tao seedling was severely infested with nematodes in these tests.

To study inheritance further, flowers of Bound Brook Red Leaf, a nematode-susceptible variety, were pollinated with P. I. 55886 (Yunnan) pollen. Eighteen seedlings from this cross were entirely free of root-knot after one season's growth in infested soil (Fig. 1). These results indicate that the character nematode resistance is dominant in the Yunnan type as well as the Shalil, and may be transmitted through either the male or the female parent. The data suggest also that the Yunnan is homozygous for this character, but a larger population would be necessary to establish this fact. The use of Yunnan or Shalil pollen on a self-sterile, susceptible variety to produce resistant seed might be feasible under certain conditions.

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The Effect of the Rootstocks on Nine Years' Growth and Yield of Four Apple Varieties[1]

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THE growth and yield performance of apple trees budded on several rootstocks and set out at Kearneysville, West Virginia, 9 years ago is outlined here in order to record such influence of the rootstocks as has been observed through the 1941 season; this period of observation includes the early-bearing stage of development up to the time of removal of the fillers in three of the four varieties. The site and the arrangement of this orchard and its growth in the pre-bearing period were described in previous reports (2, 3). The scion varieties are Gallia Beauty, Starking, Staymared, and York Imperial. They are budded both on seedling and on clonal rootstocks.

The seedling rootstocks are from open-pollinated seed from the varieties Delicious, Grimes Golden, Jonathan, McIntosh, Northern Spy, Rome Beauty, Wealthy, and Winesap. Seedlings from these sorts were chosen either because they were among those sometimes used in nurseries or because they have been suggested as possessing certain desirable qualities for rootstocks; furthermore, seed from them could be obtained from cider apples in quantity and at moderate cost. French Crab, at one time the most generally used apple rootstock in commercial nurseries, also is represented in this orchard.

The clonal rootstocks are the clone Northern Spy; Malling I, XIII, and XV; and five clones from the United States Department of Agriculture, designated by numbers 313, 316, 317, 323, and 329. These five originated from seedlings selected from commercial sources. Most of them were from seed known to nurserymen as "Vermont Crab", a term which probably included a considerable proportion of seed from standard orchard varieties as well as from naturalized seedlings in the New England States. The majority of these clones have induced better than average growth on several varieties besides being reasonably easy to propagate asexually by the usual methods.

The trees were planted 20 by 20 feet apart in units of six trees on each rootstock and with a few exceptions units were distributed in four places in the orchard. Rootstocks 316 and 329 are in alternate third rows to serve as standards with which to compare the others. In the majority of the combinations, the original number of 24 trees set had been reduced by losses, but in some combinations the full 24 trees remained until the fillers of the Starking, Staymared, and York Imperial varieties were removed in the winter of 1941–42. The fillers of the Gallia Beauty variety were left since they had not become sufficiently large to interfere with orchard cultural operations.

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YIELDS THROUGH THE 1941 SEASON

Table I presents the average total yield per tree for all varietal and rootstock combinations from the start of bearing through the 1941 season in comparison with yields of the adjacent trees on 329.

TABLE I—AVERAGE TOTAL YIELDS IN POUNDS PER TREE OF 9-YEAR-OLD APPLE TREES ON KNOWN ROOTSTOCKS AT KEARNEYSVILLE, WEST VIRGINIA (TREES ON EACH ROOTSTOCK COMPARED WITH THOSE ON ADJACENT NO. 329 ROOTSTOCK AS STANDARD)

Rootstocks	N*	M	D	S.E.D.	Rootstocks	N	M	D	S.E.D.
Gallia Beauty					*Starking*				
Jonathan (s)	15	274	+78	8.54	316 (c)	63	40	+ 27	4.89
323 (c)	18	229	+74	8.60	Malling I (c)	22	24	+ 15	3.87
316 (c)	63	237	+74	10.19	323 (c)	17	23	+ 14	3.74
317 (c)	24	260	+69	9.05	317 (c)	17	28	+ 13	3.60
Northern Spy (s)	18	147	+35	7.74	Northern Spy (s)	20	16	+ 7	2.82
McIntosh (s)	20	214	+23	7.41	Jonathan (s)	22	24	+ 5	2.00
Malling XIII (c)	12	160	+ 5	9.00	313 (c)	20	13	+ 4	2.64
Northern Spy (c)	19	101	-11	5.83	McIntosh (s)	16	19	+ 4	2.64
313 (c)	23	98	-14	7.28	Delicious (c)	16	13	+ 4	2.82
Malling X (c)	12	136	-19	8.18	Northern Spy (c)	22	21	+ 2	3.74
Winesap (s)	23	78	-34	6.78	Wealthy (s)	24	21	+ 2	2.82
Rome Beauty (s)	20	148	-43	7.87	Malling XV (c)	23	20	+ 1	1.73
Wealthy (s)	19	151	-45	7.54	Winesap (s)	19	8	- 1	2.44
Malling XV (c)	23	146	-50	8 48	Grimes Golden (s)	22	13	- 2	2.23
French Crab (s)	24	142	-54	7.41	Rome Beauty (s)	21	11	- 4	1.73
Delicious (s)	23	95	-60	7 68	Malling XIII (c)	18	4	- 5	2.00
Grimes Golden (s)	24	122	-69	8.30	French Crab (s)	14	10	- 9	3.60
Staymared					*York Imperial*				
316 (c)	77	165	+68	8.36	317 (c)	22	187	+103	10.14
Northern Spy (c)	20	123	+66	8.12	323 (c)	21	127	+ 70	8.30
317 (c)	20	189	+53	7.21	316 (c)	90	140	+ 66	8.64
323 (c)	21	123	+52	7.21	Jonathan (s)	21	107	+ 22	5.00
Northern Spy (s)	19	109	+52	7.21	Northern Spy (s)	20	88	+ 19	6.78
Jonathan (s)	20	168	+43	6.55	Malling XV (c)	23	104	+ 19	5.74
Wealthy (s)	22	141	+16	6.16	McIntosh (s)	11	98	+ 14	4.79
French Crab (s)	24	140	+15	5.56	Malling XIII (c)	17	60	+ 3	4.69
Malling XV (c)	21	134	+ 9	3.46	Rome Beauty (s)	23	84	0	3.60
313 (c)	21	61	+ 4	5.19	313 (c)	23	66	- 3	5.65
Malling I (c)	19	74	+ 3	4.00	Wealthy (s)	22	77	- 8	4.69
Winesap (s)	21	40	-17	5.83	French Crab (s)	21	72	- 13	4.69
Malling XIII (c)	21	45	-26	5.09	Grimes Golden (s)	18	60	- 24	5.74
Delicious (s)	21	40	-31	5.47	Winesap (s)	13	44	- 25	6.32
McIntosh (s)	12	104	-32	5.65	Delicious (s)	13	28	- 29	5.29
Rome Beauty (s)	17	60	-76	8.66	Malling I (c)	11	19	- 38	6.85
Grimes Golden (s)	19	59	-77	8.77	Northern Spy (c)	18	28	- 41	7.28

*N = Number of trees; M = average total yield in pounds per tree (from start of bearing through the 1941 season). D = Differences from the yield of the given variety on 329 rootstock. S.E.D. = Standard error of differences. (c) = Clone. (s) = Seedling.

Starking:—The yields of the Starking trees have been very light. The more dwarfing rootstocks have not tended to induce heavier and earlier bearing with that variety, for the larger trees have generally produced more fruit. However, as the largest average total yield per tree is less than 1 bushel, no particular significance can be attached to the production figures for Starking.

Gallia Beauty:—The Gallia Beauty trees have been in heavy production for several years. With this variety, the larger the tree resulting from any particular scion-rootstock combination, the greater in general has been the yield. The very dwarf trees of Gallia Beauty/Northern Spy clone and the Gallia Beauty/Malling I combination are the only important exceptions.

The induction of any considerable degree of dwarfing is neither necessary nor desirable for Gallia Beauty in the Cumberland-Shenandoah Valley region. Rootstocks for trees of this variety to be grown there should be selected on the basis of considerations other than dwarfing. At Kearneysville, the trees of all combinations with Gallia Beauty as the scion variety tend to bear too young so that with rootstocks inducing any appreciable amount of dwarfing in this variety, the trees are likely to produce too heavily before they have attained a size sufficient to carry the physical load of fruit. Considerable hand thinning is usually necessitated in such instances; if this is not done, the check to the growth of the tree is appreciable and difficult problems of training are created. In West Virginia, Gallia Beauty is not likely to become a large tree on any rootstock. For this reason, rootstocks that induce maximum vegetative growth are desirable for Gallia Beauty under the conditions here.

York Imperial:—York Imperial was rather slow to come into commercial production, although in these tests it has produced more than Starking. As with the Gallia Beauty, the larger trees of York Imperial have yielded the greater amounts of fruit in most instances. The only notable exception is the combination York Imperial/Delicious which, considering its relatively large size, has yielded a very small quantity of fruit; only York Imperial/Malling I and York Imperial/Northern Spy clone, the smallest York combinations, have lower total yields. In 1937, York Imperial/Malling I, when only 5 years old and approximately 4 feet high, produced up to 300 blossom clusters per tree and set fruit on a large proportion of them. The trees of this combination are now miniature in size and are by far the smallest of any of the variety-rootstock combinations. York Imperial/Northern Spy clone and York Imperial/Grimes Golden show the same weaknesses but to a lesser degree.

Staymared:—The larger trees of Staymared likewise exhibit the tendency to produce the greater amounts of fruit, although the positive correlation between tree size and yield would not appear to be quite so marked as with Gallia Beauty and with York Imperial. The principal exceptions which have yielded considerably less than their relative tree size might indicate are Staymared/Grimes Golden and Staymared/Rome Beauty, while Staymared/Wealthy and Staymared/313 have yielded more heavily.

Summary:—The yields of all four varieties worked on French Crab have been uniformly disappointing. The trees on seedlings of Delicious, Rome Beauty, and Grimes Golden are likewise in the group of general low yielders, while those on Winesap have done but little better. On Wealthy seedlings, three of the four scion varieties here have been consistently in the lower half of the production tables.

None of the clonal rootstocks has been represented in the low production group for all four varieties, although Table I shows that certain ones, such as Malling I, XIII, and XV, and Northern Spy clone have been low with one scion variety or perhaps with two varieties.

WEIGHTS OF TOPS

Table II presents the weights of the tops of the Starking, Staymared, and York Imperial fillers. This shows that among the clonal rootstocks, 329, 316, and 317 have induced the production of tops of comparatively large size with each of the three varieties. Although no top weights are available for Gallia Beauty, the same relative situation

TABLE II—AVERAGE WEIGHT IN POUNDS OF TOPS OF 9-YEAR-OLD APPLE TREES ON KNOWN ROOTSTOCKS AT KEARNEYSVILLE, WEST VIRGINIA (TREES ON EACH ROOTSTOCK COMPARED WITH THOSE ON ADJACENT NO. 329 ROOTSTOCKS AS STANDARD)

Rootstocks	N*	M	D	S.E.D.	C.V.
Starking					
Northern Spy (c)	10	214	+ 8	6.00	14.6
316 (c)	33	209	+ 1	9.79	15.9
Malling I (c)	10	187	− 3	3.16	10.7
323 (c)	6	165	− 5	6.24	25.1
317 (c)	9	199	− 9	6.93	13.3
Malling XV (c)	12	201	− 27	5.09	20.6
Rome Beauty (s)	11	180	− 28	7.42	20.5
Delicious (s)	11	158	− 32	6.78	25 7
Jonathan (s)	12	195	− 33	5.74	39.2
McIntosh (s)	7	169	− 39	11.58	26.8
Northern Spy (s)	11	153	− 53	8.37	34.1
Wealthy (s)	12	167	− 61	7.74	28.0
313 (c)	11	143	− 63	8.25	15.3
Grimes Golden (s)	11	145	− 63	7.55	19 9
Winesap (s)	12	138	− 68	8.24	20.5
Malling XIII (c)	12	108	− 82	9.00	27.7
French Crab (s)	12	127	−101	10.04	46.3
York Imperial					
316 (c)	45	199	+ 15	5.65	16.2
317 (c)	11	203	0	9 48	14.9
Jonathan (s)	11	206	− 4	5.20	13.6
McIntosh (s)	9	194	− 9	8.54	19.3
Malling XV (c)	12	194	− 16	2.63	9.8
Delicious (s)	7	157	− 19	7.61	17.2
323 (c)	12	154	− 22	5 29	36.1
Northern Spy (s)	9	140	− 24	5.47	39.2
Malling XIII (c)	8	151	− 25	8.48	16.5
Rome Beauty (s)	12	170	− 33	5.91	7.7
Winesap (s)	10	130	− 34	6.16	30.3
313 (c)	11	123	− 41	6.63	25.5
French Crab (s)	13	149	− 61	7.81	40.0
Wealthy (s)	12	133	− 77	8.77	21.2
Northern Spy (c)	10	68	− 96	9.74	42.7
Grimes Golden (s)	9	104	− 99	12.28	53.9
Malling I (c)	4	39	−137	12.92	55.1
Staymared					
316 (c)	37	212	−14	8.00	19.8
Northern Spy (s)	8	196	−14	12.24	29.2
317 (c)	9	221	−17	4.58	13.1
Northern Spy (c)	10	180	−30	5.83	21 6
323 (c)	11	170	−32	6.16	30.5
Jonathan (s)	7	222	−32	9.48	11.8
French Crab (s)	12	207	−47	8.42	35.7
Malling I (c)	11	154	−48	6.92	24.0
Grimes Golden (s)	10	181	−57	10.09	24.0
Malling XV (c)	12	196	−58	8.00	27.5
Rome Beauty (s)	7	179	−59	12.16	44.0
Malling XIII (c)	10	139	−63	7.93	28.7
Wealthy (s)	11	188	−66	9.22	18.8
Winesap (s)	12	139	−71	8.94	41.1
McIntosh (s)	10	166	−72	8.42	31.3
313 (c)	12	118	−92	10.00	31.6
Delicious (s)	11	103	−99	9.94	32.0

*N = Number of trees; M = Average weights of tops in pounds; D = Differences from the weight of the given variety on 329 rootstock. S.E.D. = Standard error of differences. (c) Clone, (s) Seedling. C.V. = Coefficient of Variability.

apparently holds. None of the seedling rootstocks meets the general requirements for producing a comparatively large-size tree in the case of any of the four varieties.

The consistent record of 316 in producing both large tree size and heavy yield of fruit is of particular interest because this clonal rootstock propagates very readily from root cuttings.

In the group of trees possessing medium to large tops, Malling XV and Rome Beauty seedling rootstocks have been consistent performers with all four scion varieties. The varieties have fluctuated much more in size of top on all other rootstocks, both clonal and seedling.

None of the clonal rootstocks has been represented consistently in the small to medium-size group. In the case of the seedling rootstocks, Wealthy has been remarkably consistent in its influence on relative size with each variety.

None of the rootstocks has induced extreme dwarfing of the tops of all four varieties. This striking characteristic accompanying certain combinations is closely associated with the variety and one usually not predictable with certainty in advance of orchard tests. With York Imperial, the rootstocks Northern Spy clone and Grimes Golden have resulted in very dwarf trees. York Imperial/Malling I trees are miniature in size. In the case of Staymared, the rootstocks 313 and Delicious seedling have both resulted in strong dwarfing of the tops. With Starking as a scion variety, Malling XIII and French Crab have induced tops in the smallest size group. Gallia Beauty/Northern Spy clone and Gallia Beauty/Malling I have been extreme dwarfs. The latter combination usually has required staking for support because of the weak root system.

VARIETAL DIFFERENCES IN SIZE OF TOP INDUCED BY A PARTICULAR ROOTSTOCK

French Crab:—The relative size of the four varieties budded on French Crab is of considerable interest. The smallest Starking trees are on French Crab, while York/French Crab and Gallia Beauty/French Crab are of semi-dwarf stature and Staymared/French Crab trees are semi-standard as compared with those on 329.

Malling I:—In the present orchard test Malling I has revealed itself as a clonal rootstock whose varying effects on the size of top of different varieties are extreme. The Starking/Malling I trees are of practically the same size as are the Starking/329. In the case of Staymared/Malling I, the trees are semi-standards. Gallia Beauty/Malling I are dwarfs. York Imperial/Malling I are miniatures. In the light of this evidence it would appear inadvisable to recommend the use of Malling I as a rootstock expected to induce a degree of dwarfing that approaches uniformity for all varieties.

Northern Spy clone:—The behavior of the Northern Spy clone as a rootstock reminds one to a considerable extent of that of Malling I. Starking/Northern Spy clone and Staymared/Northern Spy clone have both resulted in trees that are nearly as large as those on 329. On the other hand, York Imperial/Northern Spy clone and Gallia Beauty/Northern Spy clone have resulted in trees exhibiting extreme dwarfing. The behavior of these combinations points to the variations in influence of the rootstock on different varieties.

Jonathan:—In the case of the seedling rootstocks, Gallia Beauty/Jonathan trees are larger than this variety on 329, while York Imperial/Jonathan trees are of the same size as York Imperial on 329. Staymared/Jonathan and Starking/Jonathan are considerably smaller than those varieties on 329.

McIntosh:—York Imperial/McIntosh trees are comparatively large and Gallia Beauty/McIntosh trees rank but little below Gallia Beauty/329; yet Starking/McIntosh trees are intermediate in size and Staymared/McIntosh are dwarfed in comparison with Staymared/329.

Delicious:—Delicious seedlings exert some dwarfing tendency with all four scion varieties. York/Delicious trees are in the intermediate size range for that variety; Starking/Delicious and Gallia Beauty/Delicious are comparatively smaller; Staymared/Delicious are full dwarfs. These comparisons, however, are all based on 329 as the standard. It should be noted here that this clone has produced trees definitely larger than those on French Crab seedlings, which were commonly used in the nursery to produce standard-sized orchard trees in the past.

TRUNK CIRCUMFERENCES

The trunk circumferences following the 1941 season are presented in Table III. It will be noted that the weights of tops (Table II) and the trunk circumferences (Table III) are not always in close agreement. With Staymared, the two sets of figures occur in more nearly the same relative order than with Starking or with York Imperial. Hatton (1) has observed that trees upon certain rootstocks have markedly thicker trunks in proportion to total growth than would be expected in comparison with the majority of rootstocks, as, for instance, Starking/Jonathan as here reported. However, with other scion-stock combinations, the reverse of this observation is true, as, for example, Starking or Staymared on 317.

In long-time rootstock research some changes, often of considerable magnitude, must be expected with the passing years in the relative placing of various combinations according either to growth or to yield measurements of any type.

Starking:—With Starking, while the general order is the same, Starking/Northern Spy clone has jumped from tenth place to third place in trunk circumferences during the past two years and Starking/323 has dropped from third to ninth. Starking/Northern Spy seedling has risen from thirteenth to seventh, and Starking/313 from twelfth to sixth. The inconsequential yields of Starking have had only minor, if any, influence on these changes in relative rank according to girths.

Gallia Beauty:—With the Gallia Beauty trees, a comparison of trunk circumferences previously reported at 7 years (3) with those at 9 years (Table III) shows only inconsequential shifts in rank.

York Imperial:—The various York combinations showed only slight shifts in relative position according to their trunk circumferences, with

TABLE III—AVERAGE TRUNK CIRCUMFERENCE IN MILLIMETERS OF 9-YEAR-OLD APPLE TREES ON KNOWN ROOTSTOCKS AT KEARNEYSVILLE, WEST VIRGINIA (TREES ON EACH ROOTSTOCK COMPARED WITH THOSE ON ADJACENT NO. 329 ROOTSTOCK AS STANDARD)

Rootstocks	N*	M	D	S.E.D.	Rootstocks	N	M	D	S.E.D.
Gallia Beauty					*Starking*				
329 (c)	18	385	+22	1.48	Jonathan (s)	22	429	+ 8	1.77
316 (c)	63	379	+16	3.01	316 (c)	63	420	+ 4	2.93
317 (c)	24	383	+15	1.56	Northern Spy (c)	22	395	− 5	1.67
Jonathan (s)	15	385	+11	3.15	Rome Beauty (s)	21	414	− 9	1.41
Malling XIII (c)	12	365	+ 3	3.41	Malling XV (c)	23	412	− 10	1.75
Northern Spy (s)	18	346	+ 2	1.39	313 IcO	20	382	− 18	1.47
McIntosh (s)	20	368	− 1	1.46	Northern Spy (s)	20	381	− 19	1.58
Winesap (s)	23	330	−14	1.54	Delicious (s)	16	400	− 19	2.42
Rome Beauty (s)	20	354	−15	1.47	323 (c)	17	399	− 20	2.44
313 (c)	23	330	−15	1.67	Malling I (c)	22	395	− 23	1.84
Delicious (s)	23	341	−22	1.48	French Crab (s)	14	395	− 27	2.49
Malling XV (c)	23	344	−30	1.72	317 (c)	17	393	− 29	2.04
French Crab (s)	24	341	−33	2.07	Winesap (s)	19	368	− 31	2,09
Wealthy (s)	19	329	−45	2.13	Wealthy (s)	24	382	− 40	2.32
Grimes Golden (s)	24	324	−45	2.11	Grimes Golden (s)	22	378	− 44	2.10
Northern Spy (c)	19	288	−57	2.39	McIntosh (s)	16	373	− 50	2.23
Malling I (c)	12	284	−78	3.86	Malling XIII	18	363	− 55	2.35
Staymared					*York Imperial*				
Northern Spy (s)	19	413	− 7	1.68	Jonathan (s)	21	447	+ 12	0.42
323 (c)	21	392	−19	1.71	McIntosh (S)	11	441	+ 7	3.52
316 (c)	77	412	−21	2.00	316 (c)	90	421	+ 1	1.69
Malling I (c)	19	388	−23	1.52	323 (c)	21	408	− 4	1.32
Northern Spy (c)	20	391	−29	1.70	317 (c)	22	430	− 5	1.68
French Crab (s)	24	420	−31	2.20	Malling XV (c)	23	423	− 11	1.16
Jonathan (s)	20	419	−32	1.90	French Crab (s)	21	419	− 15	1.38
Rome Beauty (s)	17	413	−38	3.75	Winesap (s)	13	382	− 16	2.15
317 (c)	20	409	−42	2.04	Northern Spy (s)	20	369	− 30	2.02
Grimes Golden (s)	19	406	−45	2.13	Delicious (s)	13	380	− 31	1.78
Wealthy (s)	22	404	−48	2.33	Malling XIII (c)	17	380	− 32	1.97
Winesap (s)	21	371	−49	2.41	Rome Beauty (s)	24	393	− 42	2.04
McIntosh (s)	12	397	−54	2.31	313 (c)	23	354	− 44	2.31
Malling XIII (c)	21	355	−57	2.38	Wealthy (s)	22	359	− 76	2.75
Malling XV (c)	21	392	−60	2.44	Grimes Golden (s)	18	348	− 86	2.94
Delicious (s)	21	348	−63	2.50	Northern Spy (c)	18	281	−118	3.43
313 (c)	21	344	−76	2.76	Malling I (c)	11	261	−151	5.30

*N = Number of trees; M = Average trunk circumferences in Mm. D = Differences from the circumference of the given variety on 329 rootstock. S.E.D. = Standard error of differences. (c) = Clone. (s) = Seedling.

York/Delicious rising from fourteenth to tenth place as the only change of any appreciable magnitude.

Staymared:—Staymared, which has been producing commercial crops for two years, including the 1940 and 1941 season, Staymared/317 fell from third to ninth place in trunk circumference, while Staymared/Malling I rose from ninth to fourth place. The Staymared trees worked on other rootstocks remain in practically the same order.

SCION ROOTING

The filler trees were not pulled; rather they were sawed off close to the ground. Hence no check on the prevalence of scion rooting was obtainable at the time they were removed. While this had probably occurred to a limited extent, an inspection in 1939 by G. E. Yerkes and the senior author, who has continued the field observations in succeeding years, indicated that this factor was hardly one of appreciable importance thus far in this orchard, even with Malling I as the rootstock.

VARIABILITY

A series of comparisons (Coefficients of Variability, Table II) by varieties was made between the top weights of the trees on clonal rootstocks and on seedlings for the purpose of studying uniformity. While a tendency towards greater uniformity was observed with the clones, the differences lacked statistical significance. In this orchard, the factor of soil variation has obscured to a large extent any superior degree of uniformity in tree performance which may be inherent in the clonal rootstocks.

SUMMARY AND CONCLUSIONS

The yields, top weights, and trunk circumferences included in this report represent the growth and yield performances through the ninth season in the orchard of four scion varieties, Gallia Beauty, Starking, Staymared, and York Imperial, worked on nine clonal and on eight seedling rootstocks. A certain few rootstocks, such as the clones Malling I, XIII, and U.S.D.A. No. 313, as well as the seedlings of French Crab, Grimes Golden, Delicious, Rome Beauty, and Northern Spy, have shown themselves to be inconsistent in performance and unsuitable in all four of the variety combinations that were used. In the majority of instances, however, a given rootstock which is not adapted to a particular scion or scions has proven satisfactory in combination with other varieties. Judging from these results it would appear hazardous to predict the general performance of any rootstock by the responses obtained with a limited number of varieties worked on that rootstock.

Weights and trunk circumferences are compared as to their general agreement and value.

No attempt has been made to forecast the absolute or relative future performance of any combination of rootstock and scion except as it has been clearly established either as a failure or as undesirable in some respect at the end of 9 years of orchard testing. The longer-term performance of any of the combinations listed, especially of those producing trees of a size less than standard, will probably indicate some as outstandingly superior and others as decidedly inferior. With Starking, Staymared, and York Imperial, trees of only moderate vigor at maturity are likely to be preferable under West Virginia conditions to those continuing to grow strongly; while in the case of Gallia Beauty a strong-growing tree is desired.

Scion rooting has not been a problem in this orchard.

While there was some indication that the trees on clonal rootstocks as a group were more uniform than those on seedling rootstocks, as measured by the top weights, the potent factor of soil variation has obscured it to a significant degree.

On the bases of trunk circumference, weight of top (where available), and yield, clonal rootstock 316 and Jonathan seedlings have induced generally excellent performance with all four varieties. Extensive grower tests of these combinations would appear to be amply justified in commercial orchards of the Cumberland-Shenandoah region, particularly where strong-growing trees are desired.

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Scion Rooting of Apple Grafts as Related to the Vegetativeness of the Scions Used[1]

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THE scion rooting of apple root grafts is said to be very common in midwestern nurseries, and the suggestion has been made that this possibly is due to the use of vigorous wood for scions. With this in mind an experiment was set up to determine if the types of wood used for scions do show differences in scion rooting of apple grafts.

Two very different types of wood were used in bench grafting commercial domestic apple seedlings. One type was collected from trees 13 years of age that were fruiting and of rather low vigor; the other showing extreme vegetativeness was from decapitated filler trees of the same age and variety. The decapitated Stayman trees were on three different rootstocks: seedling, Malling XIII, and Malling XV, all giving equally vegetative shoots. With this variety, wood was collected from trees on each stock. All other varieties, York, Starking, and Gallia were on seedling roots only. The wood from the fruiting trees usually made a single scion while the shoots of the decapitated trees were frequently as long as 5 feet. It is possible that the first year's growth from the decapitated trees was of much more juvenile nature than that usually collected from scion orchards or nursery stock, but it presented an opportunity to use wood that was very different in type from that of fruiting trees.

These grafts were planted in sandy loam soil with the upper bud exposed. The cultivation was level with no hilling, but as later discussed, some little soil must have been worked up to the plants by this practice. The graftlings were dug for observation after two years of growth.

The work with Stayman included four groups each of 40 living plants. These groups were those bearing scions from fruiting trees and scions of vigorous wood from trees with seedlings, Malling XIII and XV as root stocks. The graftlings showed respectively 50, 12.5, 0.5, and 0 per cent of scion rooting.

The York graftlings showed a little more scion rooting. The results of 44 plants with scions from fruiting trees and 80 plants with scions from very vigorous wood were respectively 77.2 and 35.5 per cent with scion roots.

The Starking graftlings had still more scion roots. Twenty-four plants made with scions from fruiting trees and 54 plants with vigorous wood scions gave respectively 100 and 20.4 per cent with scion roots.

The Gallia graftlings had the most scion roots. Forty plants made with scions from fruiting trees and 46 plants made with scions of very vigorous wood, gave in turn 97.5 and 41.3 per cent with scion roots.

It appears from these results that anyone interested in producing scion roots on root grafts in the nursery, should give preference to scions from fruiting trees. On the whole, there was no difference in

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[1] Scientific Paper No. A46, Contribution No. 1873 of the Maryland Agricultural Experiment Station.

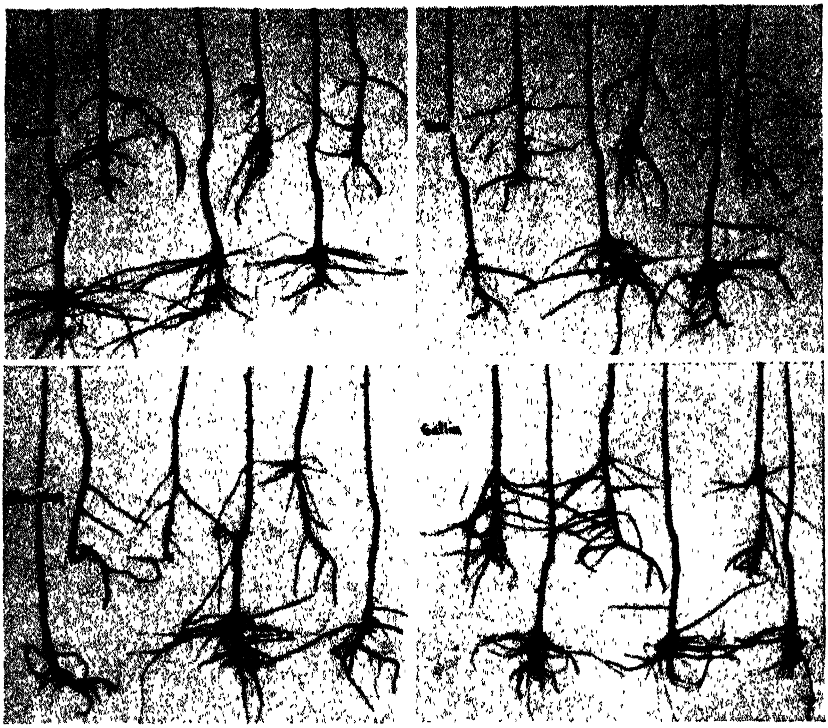

FIG. 1. Scion rooting on 2-year-old Stayman, York, Starking, and Gallia apple trees.

the size of the trees grown from the different types of scion wood.

In Fig. 1, is shown trees of the four varieties grown from the two types of wood. The three upper trees of each variety are from fruiting tree scions and the other three are from vigorous scions. The point of the graft union is seen in the pictures. The second Starking and Gallia trees from vigorous scions each have a single scion root, but qualitatively do not equal the scion rooting of the trees from fruiting tree scions. A little soil must have been worked up to these trees by cultivation as some of the scion shoots were rooted. Notice the three upper York trees, from scions of fruiting trees. The first one is scion rooted, the second has roots on the scion shoot, but none on the scion, the third has roots both on the scion and the scion shoot. In the above data all are recorded as scion rooted. Strictly speaking this scion rooting experiment has been somewhat vitiated by the slight amount of layering that accompanied cultivation, for the scion shoot when layered, roots much more readily than the scion.

When one is attempting to produce roots on the scions of root grafts the author has found it to be better not to cut the trees back the first year in the nursery for this seems to set up a condition that is not favorable for scion rooting.

A Comparison of the Variability in the Top Weight and Yield of Five Varieties of Apples Grown on Their Own and Seedling Roots

By Elmer W. Greve, *University of Delaware, Newark, Del.*

QUITE often apple trees of the same variety in an orchard will show considerable variation in growth and yield. It is sometimes possible to attribute this difference to soil conditions and other times the soil is apparently uniform. In the latter case, the seedling rootstock is often considered the cause of variation. The thought has often been expressed that if trees were grown on their own or clonal rootstocks the variability of trees in an orchard could be largely, if not entirely, overcome.

Materials and Methods

In order to determine the variability of own and seedling rooted trees, the Delaware Agricultural Experiment Station planted an orchard of five varieties in 1929. The orchard has been described by Lagassé (1). Briefly, the orchard originally consisted of the following trees: 80 Yellow Transparent, 160 Grimes Golden, 80 Delicious, 80 Stayman Winesap, and 240 Rome Beauty. Forty trees were planted in each row and there were 16 rows. The trees were 20 feet apart each way. The rootstocks of the trees in each row alternated in pairs, that is, the first two trees in each row were on their own roots, the next two on seedling roots, the next two on their own roots, and so on. In addition to this, the trees in every other row were pruned, while the remaining rows were unpruned. The trees on which this report is based were left unpruned so that the variability caused by pruning would not be a factor entering into the results.

The trees were located on sandy loam soil and they were grown under a cultivation-cover crop system of soil management. Each spring nitrate of soda was applied at the rate of ¼ pound for each year of the tree's age. Cover crops of soybeans were sown the first part of June. These were plowed down in October and a cover crop of rye and vetch sown. Muriate of potash at the rate of 75 pounds per acre and 16 per cent superphosphate at the rate of 250 pounds per acre were applied each year at the time of sowing the soybeans.

After 5 years' growth in the orchard, half the trees in each row were removed and the results have been reported by Lagassé (2). In the spring of 1942, after 13 years' growth in the orchard, the remaining unpruned trees were removed and the data in this paper are based upon these trees.

Each tree was cut off at the ground level while being held upright by three or four props placed around the tree. The tree was then raised by means of a lifting pole and trestle while platform scales were shoved beneath the trunk. It was then let down on the scales and the weight was recorded.

The yield of fruit from each tree has been recorded every year at harvest time. Fruit falling to the ground during the harvest period has been considered in the total yield. Standard statistical methods were used in analyzing the data.

TABLE I—A COMPARISON OF THE AVERAGE TOP WEIGHT PER TREE AND THE COEFFICIENT OF VARIATION OF FIVE VARIETIES OF APPLES ON THEIR OWN AND ON SEEDLING ROOTS AFTER THIRTEEN YEARS' GROWTH IN THE ORCHARD

Type of Root	Variety									
	Yellow Transparent		Grimes Golden		Delicious		Stayman Winesap		Rome Beauty	
	Weight (Lbs)	C.V. (Per Cent)	Weight (Lbs)	C.V. (Per Cent)	Weight (Lbs)	C.V. (Per Cent)	Weight (Lbs)	C.V. (Per Cent)	Weight (Lbs)	C.V. (Per Cent)
Own	(9)† 210 ±38*	54 ±16	(20) 618 ±41	30 ±5	(8) 562 ±35	17 ±4	(9) 632 ±67	32 ±8	(26) 341 ±22	34 ±5
Seedling.	(10) 166 ±40	77 ±25	(16) 548 ±49	36 ±7	(10) 482 ±36	24 ±6	(9) 524 ±48	28 ±7	(26) 331 ±21	32 ±5

*Standard Error.
†Indicates number of trees in average.

PRESENTATION OF DATA

Top Weight:—The results secured from weighing the trees are given in Table I, along with the coefficients of variation. It may be seen that the average weight of the own rooted trees was greater for all five varieties than that of the seedling rooted trees. However, none of these differences is statistically significant when compared on the basis of the standard error of the difference. At the time Lagassé (2) removed half the trees then in the orchard, at the age of 5 years, the top weight of the seedling rooted trees was greater in every case except that of Grimes Golden, in which case the own rooted trees were larger. The original weight at the time of planting was greater for the seedling rooted trees of all varieties, except Rome Beauty.

The coefficients of variation were greater for the own rooted Stayman Winesap and Rome Beauty trees, while with Yellow Transparent, Grimes Golden, and Delicious the variation of the seedling rooted trees was greater. The differences, however, were not significant.

The previous report (2) showed that the seedling rooted trees were slightly more variable in weight than the own rooted, with the exception of the Yellow Transparent variety.

It is interesting to note from Table I that the Grimes Golden and Stayman Winesap varieties have made the largest trees, regardless of the kind of roots they were growing on. Delicious ranked next in size and it was followed by Rome Beauty. The Yellow Transparent trees were the smallest.

Yield:—The yield data for a period of 6 years are presented in Table II. This data covers the period from the time the trees were 8 years old until they were removed from the orchard, after the thirteenth year. The trees bore but very little fruit before 8 years of age. The coefficients of variation are shown, also, in Table II.

TABLE II—A COMPARISON OF THE AVERAGE YIELD PER TREE AND THE COEFFICIENT OF VARIATION OF FIVE VARIETIES OF APPLES FROM THEIR EIGHTH TO THIRTEENTH YEARS, INCLUSIVE

Type of Root	Year												Average 1936–1941, Inclusive	
	1936 (8th)		1937 (9th)		1938 (10th)		1939 (11th)		1940 (12th)		1941 (13th)			
	Yield‡ (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)	Yield (Pounds)	C.V. (Per Cent)
Yellow Transparent														
Own......	53±16†	92±36	8±5	190±129	46±20	128±62	33±9	79±28	97±16	49±14	5±2	142±75	40±7	121±23
Seedling...	38±8	64±20	15±5	85±38	32±11	99±40	23±9	125±57	69±14	63±19	9±5	197±130	32±5	108±19
Grimes Golden														
Own... .	48±7	69±15	166±26	70±16	238±20	37±7	197±49	112±33	349±32	41±7	141±13	40±7	190±13	75±7
Seedling...	70±13	82±21	270±41*	61±14	247±50	83±22*	281±57	84±22	383±45	49±10	276±25*	37±7	253±16*	62±6
Delicious														
Own	2±1	121±57	49±14	86±32	55±16	86±32	89±19	63±20	146±36	73±25	37±21	168±99	63±11	126±25
Seedling...	25±8*	104±41	200±27*	43±11	44±17	120±53	192±31*	51±14	215±33	49±13	61±50	258±219	123±16*	100±16
Stayman Winesap														
Own......	86±14	48±14	128±22	53±16	205±28	41±11	173±22	38±7	86±17	59±18	248±59	72±24	154±15	70±9
Seedling .	71±13	56±17	205±23*	34±9	128±41	97±39	299±43*	43±12	222±32*	43±12	312±75	72±24	206±20*	73±10
Rome Beauty														
Own.. ...	21±5	111±29	36±7	100±24	92±14	78±16	250±32	64±12	111±13	57±10	272±9	17±2	131±6	53±4*
Seedling...	25±5	113±29	59±10	84±18	105±16	78±16	281±29	53±9	135±12	47±8	319±9*	15±2	153±4*	36±2

*Significant difference.
†Standard error.
‡Same number of trees used in computing average as is indicated in Table I.

In 4 of the 6 years and for the period as a whole the own rooted Yellow Transparent trees have yielded more than the seedling rooted trees, yet none of these differences is significant. In every year of the 6, the seedling rooted Grimes Golden trees yielded more than the own rooted ones. The difference is significant statistically in 2 of the 6 years and for the average yield over the 6-year period. With Delicious the seedling rooted trees had the greater yield in 5 of the 6 years. Here again, the difference is significant in 2 of the years and for the period as a whole. In 4 years of the 6 the seedling rooted Stayman Winesap trees yielded more than the own rooted trees. The difference is significant in 3 of these years and for the average yield over the 6-year period. The differences in the 2 years when the own rooted trees yielded more are not significant. The yield of the seedling rooted Rome Beauty trees was greater every year, but this difference was significant in only one year. However, the difference in favor of the seedling rooted trees is significant for the average yield per tree over the 6-year period.

With the exception of Yellow Transparent, all varieties have yielded significantly more for the 6-year period when growing on seedling roots. In a previous report, Lagassé (3) presented as a matter of record, the yield of the trees for the years of 1935 and 1936. At that time the seedling rooted trees, with the exception of Yellow Transparent, had averaged more fruit per tree than the own rooted trees.

In only one year is there a significant difference in the coefficient of variation for yield. This was for Grimes Golden in 1938 when the yield of the seedling rooted was more variable than that of the own rooted trees. The coefficient of variation for the average yield per tree over the 6-year period shows a significant difference for only one variety. This was for Rome Beauty in which case the own rooted trees were more variable than the seedling rooted ones.

DISCUSSION

Although seedling rootstocks have often been thought to be the cause of variation in the growth and yield of trees in an orchard, the present study does not bear this out. Shaw (4) has reported, also, that he is firmly convinced that variation in growth and yield of trees in an orchard is due to other causes than the seedling rootstock commonly used. Although, he found that Wealthy trees were more variable on seedling rootstocks than on any clonal stock, with McIntosh, on the other hand, only one clonal rootstock was less variable than the seedling rootstocks.

The coefficients of variation show that the variability in top weight of the trees has been greatly reduced from the variability in tree weight at the end of 5 years' growth in the orchard, as reported by Lagassé (2). The only exception to this is the own rooted Yellow Transparent trees which show more variability. Although the trees, with this exception, became less variable in weight with age, the rootstock they were growing on had no significant influence.

With the seedling rooted trees after 13 years' growth in the orchard, the Grimes Golden variety was the largest and Stayman Winesap was next. Delicious was the third largest. These varieties are in the same order they were after 5 years' growth (2). Rome Beauty was the next to the smallest and Yellow Transparent was the smallest. These two varieties reversed the order of weight between the fifth and thirteenth years. The ranking for weight of the own rooted trees is the same as that for the seedling rooted ones, except that the Stayman Winesap trees were larger than the Grimes Golden. It seems that the weight of tree is determined by the above ground part and not by the roots on which it is growing. It is characteristic for a variety such as Stayman Winesap to make a larger tree than Rome Beauty. This happens regardless of the rootstock the variety is growing on.

SUMMARY

Yellow Transparent, Grimes Golden, Delicious, Stayman Winesap, and Rome Beauty apple trees on their own and on seedling roots were grown for 13 years in an orchard. At the end of this period, the trees were cut off at the ground level and the weights of the tops obtained. Yield data for the trees are presented for a period of 6 years, from the time they were 8 years of age until the thirteenth year, inclusive. In addition, the coefficients of variation for both top weights and yield are given.

Although the top weights of all varieties were greater when grown on their own roots than when grown on seedling roots, the differences were not significant statistically. Neither were there significant differences in the variability of top weights.

With the exception of Yellow Transparent, the average yield per tree of the seedling rooted trees was significantly greater than that of the own rooted trees for the 6-year period. The variability in yield for this period was greater for the own rooted trees, with the exception of Stayman Winesap. However, the only significant variation is that of Rome Beauty.

In conclusion, yield of fruit was not increased and variability in top weight and yield was not reduced by growing trees on their own roots in comparison with seedling rooted trees.

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Apple Stocks Exhibiting Noninfectious Hairy Root and Their Use in Bench Grafting

By E. A. SIEGLER, *Bureau of Plant Industry Station, Beltsville, Md.*

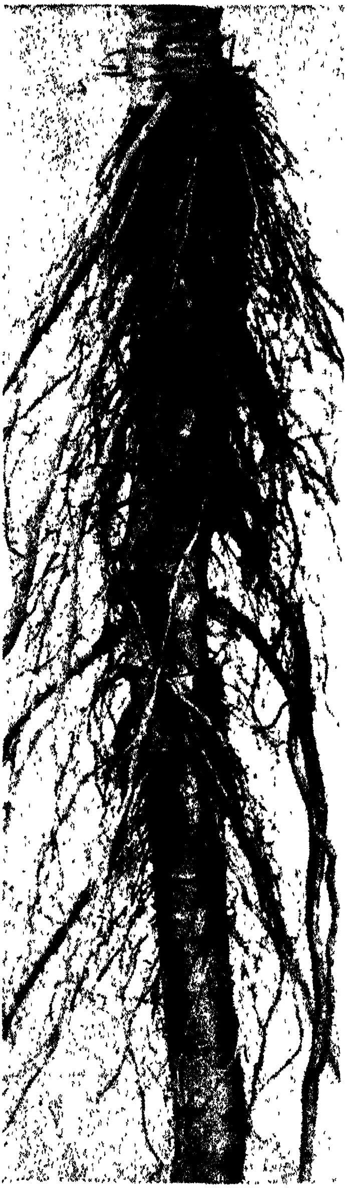

FIG. 1. Original 1-year seedling of clone 21 (natural size).

TO produce apple trees on clonal roots it is customary to bud the desired variety on stem-rooted stocks obtained from mound-layers. The production of such trees is largely confined to England and, in the United States, to New York where it is the practice to propagate trees by budding. The rootstocks generally employed have been developed at East Malling, England, mainly from material known as Paradise and Doucin stocks. Such stocks have been used to produce trees smaller than normal or "standard" trees and, regardless of the amount of reduction in size effected, are referred to by horticultural authorities as dwarfing stocks. These stocks are, in general, characterized by morphological and other features which permit some differentiation between them and other types of rootstocks.

The experiments and observations reported here were made with material which is judged to be similar to the Malling clones. This report is an attempt to describe the appearance and behavior of this material in comparison with what may be referred to as normal clones and, in addition, experiments are reported on the production of clonal-rooted trees by bench-grafting scions of the desired variety on stems obtained from 1-year rootstocks propagated by root cuttings. This method of propagation could be used in those nurseries accustomed to bench-grafting and, under certain conditions, might have other advantages.

The immediate problem has been to demonstrate that the basal portions of the stems of these rootstocks can be used in the same manner as pieces of seedling roots in bench-grafting and under conditions where the graft-union is ultimately at or above the ground level. It is apparent that no new method of propagation is involved but rather a combination of practices designed to utilize the growth characteristics of the type of material employed.

MATERIALS AND METHODS

The supply of rootstocks was obtained by growing root cuttings of clonal material originally taken from 1-year domestic seedlings (Fig. 1) of commercial varieties selected because they exhibited symptoms of noninfectious hairy root (2). Since the results of this test have depended so largely upon the type of rootstock used, it seems necessary to describe this material at some length later in this report. When the plants growing from the root cuttings had made about 6 inches of growth, a ridge of dirt was drawn to them so as to cover about one-half of the new growth. This ridge was later increased to 6 inches (Fig. 2). When examined in the fall following a dry summer, these mounded shoots in general were but sparsely rooted. Because of the known propensity for such material to develop roots, however, they appeared suitable for the purpose of this experiment.

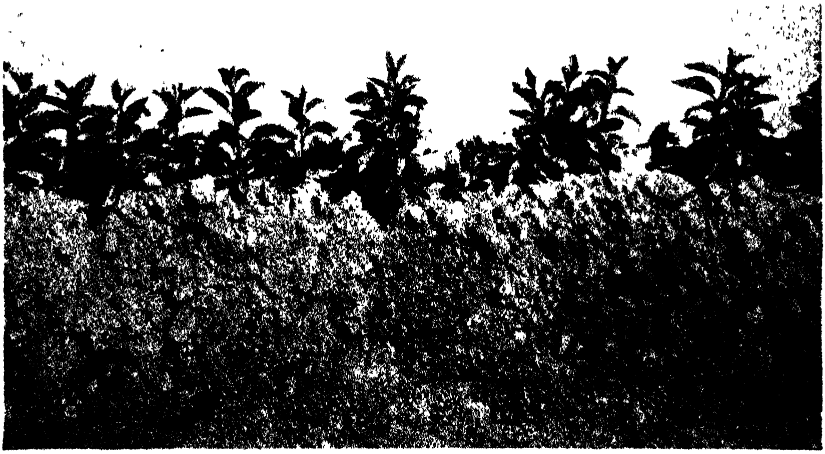

FIG. 2. Mounded root cuttings in July.

The variety scions were grafted in February on the basal 4- to 5-inch pieces of these stocks approximately at the region where the stem-tissue had been exposed above the mounded plants and the grafts were stored for callusing. The grafts were planted at Beltsville, Maryland, and set so as to place the union about 1 inch above the ground level, and then a 3-inch ridge of dirt was drawn to the grafts to cover the union. To prevent scion rooting, most of this ridge was drawn away from the grafts when the new shoot growth had reached about 10 inches. This method of grafting and treatment of the grafts (Fig. 3) had proved successful in previous years with 1-year seedlings as rootstocks.

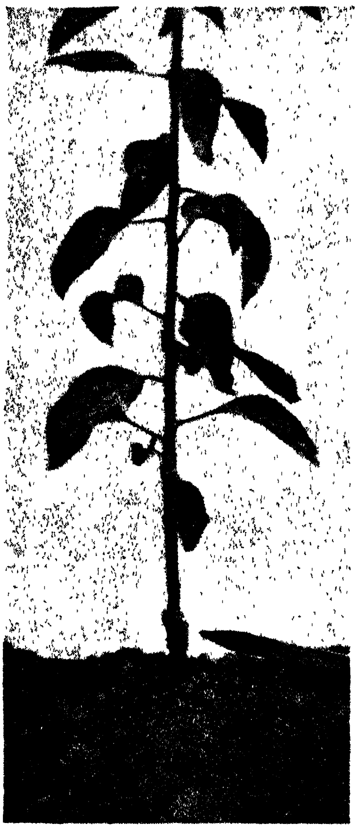

FIG. 3. One-year graft in July. Pointer indicates graft union.

RESULTS AND DISCUSSION

The results of the experiment are shown in Table I.

It is believed that the small number of grafts in these experiments does not materially militate against the practical demonstration that the method involved is feasible. Additional tests over a period of years of course would be necessary for proper evaluation, but for the present it is desirable to emphasize that the results obtained with this method are largely due to the nature of the material employed.

The excellent stand and size of these grafts may be attributed partly to favorable growing conditions. Previous experience, however, with similar grafts on seedlings of this type indicated that some increase in stand and in size is to be expected even under adverse growing conditions in comparison with normal grafts.

The seedlings from which these rootstocks originated were selected solely on the basis of morphological characteristics for long-term experiments planned to test the hypothesis that "hairiness" is generally associated with a dwarfing tendency. Observations over a number of years on thousands of seedlings have indicated that 1-year seedlings which exhibit pronounced "hairiness" are consistently small; conversely, the largest seedlings are generally "smooth". There is also a pronounced tendency for such "hairy" clones to surface-root, resulting in subsequent domination of the entire root system by the proximal roots (2).

TABLE I—STAND AND GROWTH OF BENCH-GRAFTED ROME BEAUTY SCIONS ON ONE-YEAR SHOOTS (PREVIOUSLY MOUNDED) OF SEVERAL CLONAL ROOTSTOCKS (1942)

Rootstock Clone	Number Grafts Planted	Stand One-Year Grafts (Per Cent)	Average Height (Inches)
No. 21	27	92	34
No. 27	10	90	37
No. 43	15	100	30

It is difficult to describe adequately this material because there are no generally accepted bases for terminology. The apparent interdependence of morphological features, vegetative responses and environmental conditions for growth also serve as complicating factors. Nevertheless, it is highly desirable to attempt a description which will serve as a basis for comparison with other types of clones.

The root systems of the original seedlings were representative of a type commonly found in seedlings from our domestic varieties, which has been variously referred to as "hairy root", "noninfectious hairy root", "fuzzy roots", "crown roots", "fibrous roots", and so on. Under the necessity of resorting to generalities, these seedlings can best be considered as representative of a type intermediate between those with small-caliper, short, unbranched tap roots, practically covered with small hair-like roots and those with large-caliper, long, branched root systems devoid of tufts or masses of hair-like roots, but possessing normal amounts of finely-divided feeding roots.

Further investigations are necessary to establish better bases for comparison but at present the three clones used here are judged to be intermediate between the original seedling of the pronounced dwarfing clone Malling IX and the original seedling of the "standard" clone USDA 323. The Malling clones were selected by Hatton and co-workers, among other reasons, because they were readily propagated by mound-layering; the clones developed in America by Yerkes, such as USDA 323, were found to propagate more readily by root cuttings (3). Both groups of workers propagate the nursery trees by budding. The English workers bud into the rooted stems taken from the mounded mother plants and previously lined out; the American workers bud into the stem of the entire plant including the original root piece.

These differences between methods probably have been partly the result of differences in objectives. The earlier Malling selections were developed from material used for dwarfing purposes and those clones that produced pronounced dwarfing effect, for example, Malling IX, rarely produced roots large enough to be used successfully as root cuttings. Such clones, generally characterized by a pronounced "hairy" appearance and frequently associated with burr-knotting, do propagate readily by mound-layering. The earlier American selections were selected to produce standard-size trees; they produced branch roots sufficiently large in caliper to be used successfully for root cuttings.

As an example of the material used in the present experiments, the original seedling of clone 21 was classed as a moderate type of noninfectious hairy root. It was selected because the caliper was unusually large and because some of the numerous branch roots, necessarily small, were borne far down on the main axis. When used as a rootstock, surface or crown rooting later should be so slight as to have but little effect on the more distal parts of the root system of the mature tree. Disregarding physiological incompatibilities and other factors, it is thought such a clone should have a slight dwarfing effect in comparison with a clone from a seedling identical in all respects except the noninfectious-hairy-root characteristics.

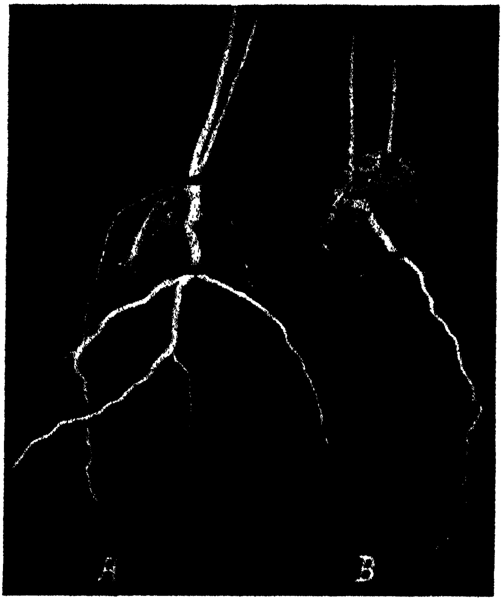

FIG. 4. One-year (mounded) plants from root cuttings. Original root pieces indicated by black markings. A, Clone USDA Vt. 323. B, Clone 21.

The 1-year plant (Fig. 4, B) of this clone, grown from a root cutting and the 1-year graft (Fig. 5, A) show somewhat more surface rooting and "hairiness" than had been expected. In comparison, the 1-year plant from the USDA 323 clone (Fig. 4, A) shows sparse stem-rooting and typical large but few branch roots. The 3-year plant of clone 21 (Fig. 5, B) grown from a root-cutting, however, shows comparatively little surface rooting although the proximal portions of the branch roots exhibit hairiness.

This difference in appearance is due to the treatment the plants received; the stem tissue on this plant had not been mounded, and accordingly opportunity was not afforded for rooting at this region. The moderate manifestation of hairiness on the original seedling is thus seen to be somewhat accentuated on stem tissue when

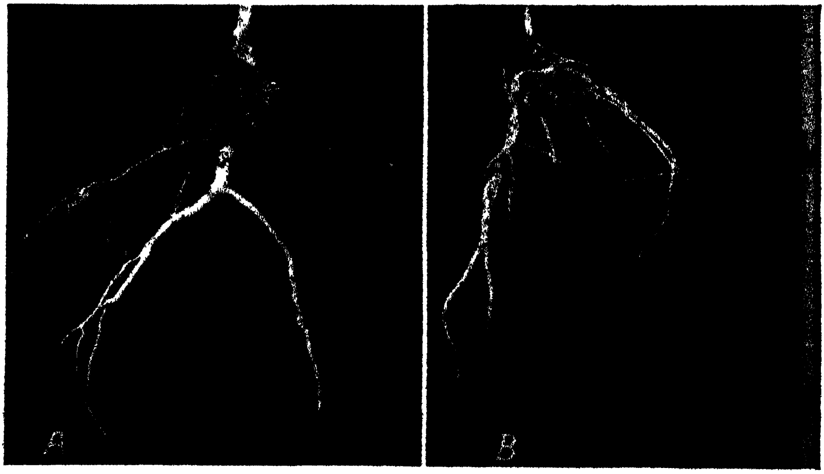

FIG. 5. A, One-year graft on clone 21. B, 3-year plant of clone 21 grown from a root cutting (reduced more than A); no opportunity for stem rooting; degree of hairiness about same as on original seedling (see Fig. 1).

this tissue was grown under conditions favorable for rooting (Fig. 4, B; 5, A), but when conditions were not favorable for rooting (Fig. 5, B), particularly on comparatively young tissue, the degree of hairiness is approximately the same as that on the original seedling. Little, if any, dominance over the distal parts of the root system on this older plant is apparent; this condition conforms with the appearance of the original seedling. Although this explanation of the differences in appearance of the root systems of the three plants of this clone may be subject to modification, these differences illustrate the rooting responses of this type of material and emphasize the need for careful consideration of all conditions for growth when making descriptions of morphological features of root systems.

Under advantageous conditions for growth and with soil conditions favorable for root extension, and so on, there appears to be a definite relation between the amount and the type of root growth exhibited by the proximal and by the distal regions of the root system of this type of material. In those clones in which the original seedlings show a pronounced "hairy" condition, dominance by the proximal or "surface" roots is, under favorable conditions, so pronounced that there results little or no extension of a normal number of roots of large caliper. The recent report by Bowman (1) in Australia, on older plants, illustrates these types of root development and is in harmony with observations reported (2) on rooting responses in younger plants.

A discussion of the relative merits of propagating fruit trees by budding and by bench-grafting is not undertaken in this report. Both methods have advantages, particularly under certain conditions. Likewise, many factors must be considered in evaluating the merits of propagating rootstocks by mound-layering and by root cuttings. But since there is no evidence that the merits of a rootstock are dependent upon the method, *per se*, by which it is propagated, it seems desirable to test material such as is described here.

SUMMARY

Experiments are reported on the propagation of apple trees on clonal rootstocks developed from 1-year seedlings whose root systems appeared slightly "hairy". Such root systems are thought to represent a type intermediate between the more dwarfing Malling clones and the "standard" USDA clones. A description of these root systems is given.

These experiments were designed to test this material under a combination of methods not commonly practiced, and thus to afford alternatives in propagation methods suitable for this type of material. The supply of rootstocks was obtained from several clones that propagated readily from root cuttings. The basal pieces from the mounded stems of the 1-year plants were bench-grafted with scions of the desired variety.

The 94 per cent stand obtained from a planting of 52 grafts indicates that the method may be practicable with the type of material employed.

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Rootstock Influence on the Composition of Valencia Orange Fruit

By F. F. HALMA, *University of California, Los Angeles, Calif.*

THAT rootstock species affects the total solids, acid, and solids-acid ratio of a number of the citrus fruits was the conclusion of Hodgson and Eggers (3) after they had made a study of various fruits from the Subtropical Horticulture laboratory orchard on the campus of the University of California at Los Angeles. The fruits reported were: Washington Navel and Valencia orange, Marsh grapefruit, Eureka and Lisbon lemon, and Bearss lime. Of the five rootstock species investigated — Trifoliata orange, sour orange, sweet orange, grapefruit, and rough lemon — Trifoliata orange, the most dwarfing stock, produced the highest per cent of soluble solids in the fruit of all six varieties; the rough lemon, however, the most vigorous stock, gave the lowest value. Conversely, rough lemon produced the lowest per cent of citric acid, and Trifoliata the highest per cent. The solids-acid ratio was relatively high in both cases.

These rootstock effects were subsequently confirmed and extended by Richards (5), who used Navel and Valencia orange, Marsh grapefruit, Satsuma and Dancy tangerine produced in the same orchard. Lynch (4), on the other hand, reports that the Persian lime in Florida is not affected by rough lemon, grapefruit, Bittersweet and Sour orange, and Cleopatra and Willowleaf mandarin rootstocks.

This report directs attention to a rather marked rootstock effect on the juice of Valencia orange. The rootstock, Eureka lemon, is not used commercially as a rootstock, but for the purpose of studying scion-rootstock relationships, 20 trees of this combination were included in a planting made in 1931. Since there are many types or strains of

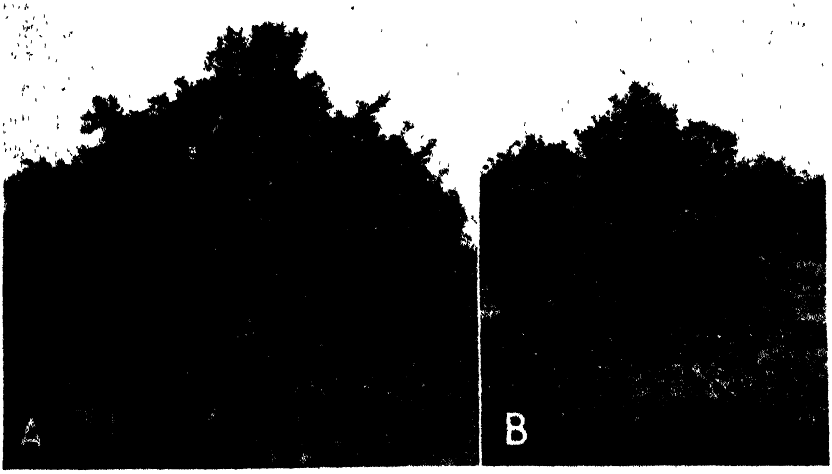

FIG. 1. Rootstock influence on size of 10-year-old Valencia trees. A, on sweet orange; B, on Eureka lemon. Photographed 25 feet from trunk.

Eureka it is important to mention that the type used in this investigation is characterized by early and heavy bearing and by comparatively low vigor. Field observations (2) indicate that the widespread lemon tree decline in California has its primary cause in the propagation of this type. Because the Eureka lemon is extremely variable when grown from seed, the trees were propagated by the twig graft method (1). Briefly, the method consists of grafting a Valencia twig on to a Eureka lemon twig and then rooting the combination as one does an ordinary citrus cutting. Planted in the same orchard and close by are Valencia on their own roots, and budlings on sweet orange stock.

Fig. 1 shows the dwarfing effect of the Eureka lemon stock on the Valencia scion. The larger tree, which is about twice the size of the other, is on sweet orange stock. Lest it be assumed that the asexual method used in the propagation of the lemon rootstock was a factor, it should be mentioned that the own-rooted Valencia trees were of the same size as the budlings on sweet orange stock; the fruit likewise was of similar composition.

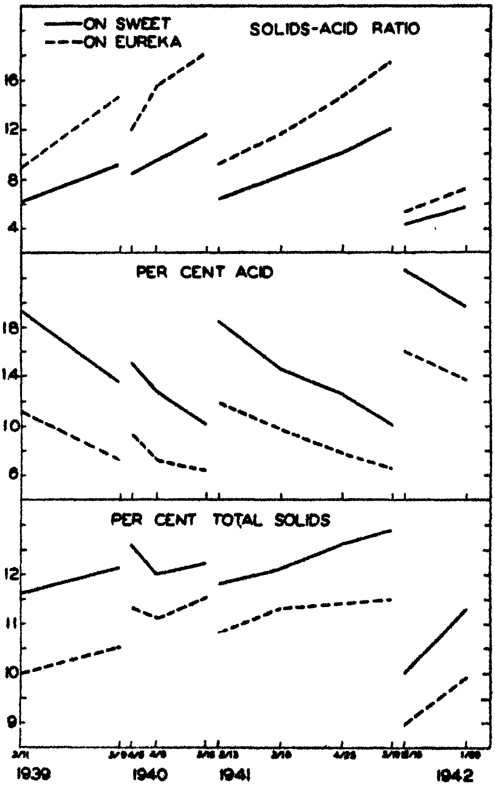

Fig. 2. Influence of rootstock on total solids, acid, and solids — acid ratio in Valencia orange fruits.

Except for their smaller size, the trees on lemon stock appeared to be normal in leaf color and bearing habit, at least they were judged to be so during their ninth, tenth, eleventh, and twelfth years in the orchard when the fruit samples were taken.

The effect of the lemon stock on the composition of the fruit is interesting because the data do not support the general belief that dwarfing rootstocks necessarily heighten fruit quality.

Before carrying this discussion further, a brief statement concerning sampling is in order. All fruits were collected by the writer. Each point in the graphs represents the average of from two to four samples of 14 fruits each. Since there is a difference in the composition of the fruit of north and south exposures, separate samples from each side of the tree were taken. The juice was extracted by a hand reamer, and the soluble solids and citric acid were determined by the official method used in the maturity test in California.

The data are summarized in Figs. 2 and 3. The 11 samples, taken over a period of four seasons, are representative of various stages of fruit development. It is seen that throughout this period the Eureka lemon stock caused the fruit to be lower in total solids and acid; furthermore the solids-acid ratio was higher than in the fruit from trees on sweet orange rootstock. Since a ratio of 8 parts of soluble solids to 1 part of acid is the legal standard of maturity for oranges in California, it is of interest to note that the fruit from the trees on lemon stock reached this standard about 2 months earlier than that from trees on sweet orange. Because of the relatively low acid content, the fruit from the trees on lemon had a flat taste. Further differences are that the fruit produced by the lemon root had, in most cases, a greater per cent of rind, less juice on the basis of whole fruit weight, but an equal amount on the basis of edible portion.

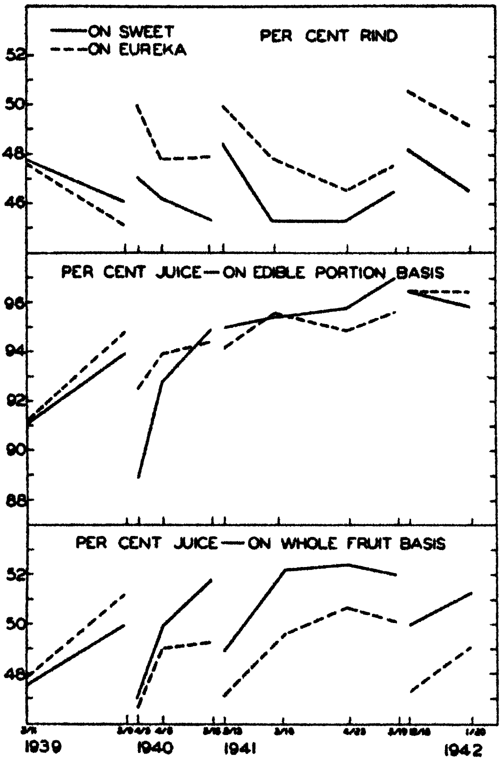

FIG. 3. Influence of rootstock on amount of juice, rind, and juice in edible portion in Valencia orange fruits.

In conclusion it should be pointed out that while Eureka lemon is undoubtedly responsible for the effects on the size of tree and on the fruit composition, it does not necessarily follow that other lemon varieties will produce similar effects. For example, certain strains of the Lisbon or Villafranca lemon, which differ from the Eureka by their greater vigor, greater cold-resistance, and bearing habit, might react differently with the Valencia orange. It would also be of interest to know whether the lemon effect herein reported would also be transmitted through a lemon interstock of double-worked trees.

The effect of Eureka on tree growth in Valencia is opposite to that of Rough lemon but its effect on fruit characteristics and quality is similar. This is interesting and probably has special significance.

SUMMARY

As a rootstock, Eureka lemon compared with sweet orange stock not only has a marked dwarfing effect on the Valencia orange, but it also produces fruit with a lower per cent of total solids and acid, a higher solids-acid ratio, a thicker rind, but an equal amount of juice in the edible portion of the fruit. The results obtained do not substantiate the general belief that dwarfing rootstocks necessarily heighten fruit equality.

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Virginia Crab as an Own-Rooted and an Intermediate Stock[1]

By J. A. McClintock, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

IN MOST of the experimental work in which Virginia Crab has been used, an effort has been made to provide favorable conditions for this variety to become an own-rooted stock. The length of time required for scion roots to develop varies with the conditions favoring root production. Efforts to speed up scion root production by means of wire constrictions at the union of whip grafts frequently results in stimulating sucker formation from buds on the French crab understock. Such French crab suckers, if not promptly removed, nourish the seedling roots, and tend to perpetuate them beyond the time when they are needed; therefore the use of wires or other constrictions at the union do not serve the desired purpose, namely, own-rooting of the scions.

Studies with organic acids and amides in various carriers, such as lanolin or talc, have proved beneficial in stimulating scion rooting. When scion roots develop from Virginia Crab stem tissues they soon take over the functions of roots for such plants with the results that the French crab roots gradually disintegrate as though starved.

Own-rooting of Virginia Crab can also be accomplished by layering without the aid of root promoting substances, but studies indicate that in such cases root development is neither as rapid nor as abundant as where organic substances are used. Even with the best methods yet developed the production of own-rooted Virginia Crab stocks is a longer, and a much more expensive process than raising apple stocks from seeds. It is also doubtful whether own-rooted Virginia Crab stocks can be produced as economically as the various Malling types, because Virginia Crab, as used in our studies does not show the free rooting, burr-knot characteristics so evident in the Malling selections.

The above mentioned difficulties in obtaining own-rooted Virginia Crab stocks have raised the question, Will Virginia Crab, as an unrooted intermediate, produce the desirable effects on top worked commercial varieties which have been obtained experimentally with known own-rooted stocks of Virginia Crab? While opinions have been expressed that it is not necessary to have Virginia Crab on its own roots to obtain its desirable effects on top worked varieties, published experimental evidence to substantiate such opinions has not come to the writer's attention. There is evidence that some scion varieties influence the root development of the seedling stocks, but experimental evidence that desirable characteristics, such as resistance to low temperatures and to diseases and insects, are transmitted from the scion to the stock has not established such theories. It is therefore not sound to theorize that Virginia Crab, budded or grafted on French crab seedlings so that it functions as an unrooted scion or intermediate variety, will impart to the French crab understocks the cold hardiness, and the resistance to collar rot, fire blight, and woolly aphis for which Virginia Crab has been proven superior to French crab. Thus in the short chain which is composed of French crab seedling, Virginia Crab intermediate and Grimes, or some other commercial variety as the fruit bearing area, the French crab seedling is decidedly a weak link which will constantly threaten the ability of the strong middle link to assert its full value. Ample experimental evidence has been presented to indicate that shortening the chain to two links by eliminating the weak French crab as early as possible will result in a stronger and more reliable chain. The ideal is a two-link chain from the start, but until such chains can be forged more rapidly than at present, it seems advisable to attach the third link with the expectation of not depending upon it any longer than necessary, that is, only until Virginia Crab roots have developed.

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[1] Journal Paper No. 70, Purdue University Agricultural Experiment Station.

It is not the function of this paper to compile the evidence on grafting versus budding as a means of attaching the French crab and Virginia Crab links, but the writer favors whip grafting to facilitate Virginia Crab scion rooting. This will more rapidly enable the chain to cease its dependence on the weaker French crab seedling link.

The final answers to stock-scion problems will come only after years of careful study; therefore it is an obligation, to our fellow workers and to those who are producing fruit for food, to present evidence which will help guide the industry toward more reliable and economical fruit production. Only in experimental work does one deliberately set up stock-scion combinations which make it impossible for a given stock to exert its greatest possibilities. This was done by the writer in the case of Virginia Crab, by budding into French crab seedlings at distances above the ground which would insure that the Virginia Crab could not produce scion roots and would therefore remain a true intermediate. To accomplish this the French crab seedlings were pruned to whips, and as they reached sufficient trunk diameter they were budded to Virginia Crab at heights ranging from 6 inches to 52 inches above the soil. For comparison with these true intermediate combinations, Virginia Crab was either whip grafted using a long scion on a short piece of French crab seedling root, or budded on French crab seedlings, at, or near the crown, and the Virginia Crab scions subsequently covered with soil for several inches to encourage own-rooting. As the plot where these trees were started was fertile and favorably located for the development of diseases and insects it was decided to continue the studies in closer than orchard distances rather than move the trees to less desirable soils to allow for greater spacing. During the seven years since these studies were started, various differences have developed which are here recorded as evidence regarding the merits of using Virginia Crab as an own-rooted stock and as an unrooted intermediate.

One conspicuous difference between the two groups of trees was the presence of numerous suckers and lateral branches which developed from the crowns and trunks of the high-worked French crab stocks. The recurrence of such suckers and seedling branches necessitated extra labor each year for their removal, and in a few cases they were directly responsible for fire blight cankers developing on the trunks below the union. Less conspicuous than fire blight cankers, but obviously a source of danger to certain top-worked varieties, were blotch cankers on the French crab trunks at heights ranging from 1 to 17 inches above the ground. Some of these blotch cankers had spread from the initial infections so that they completely surrounded the trunks. As no blotch cankers were found on any of the Virginia Crab growth it is concluded that this variety is quite resistant to infection by the blotch fungous, *Phyllosticta solitaria* (E. & E.).

Growth records taken for a number of years on other stock plots indicate that own-rooted Virginia Crab stock are among the most vigorous and also produce Grimes trees larger than those on French crab seedlings. It is therefore considered that the growth of Virginia Crab as un-rooted intermediates on French crab seedlings compared with own-rooted trees of similar age give an indication of the value of the two types of roots in the production of Virginia Crab tops for scaffold working. In the case of own-rooted Virginia Crab the measurements are taken near the ground level. Measurements of such trees, 7 years of age, ranged from 2 inches to 5 1/16 inches in diameter with the average 3 10/16 inches in diameter for 23 trees grown in closer than orchard stands. For 130 own-rooted Virginia Crab 7 years of age transplanted to 20 by 20 feet the trunk diameters ranged from 2 10/16 to 5 8/16 with an average of 4 1/16 inches in diameter. With the Virginia Crab, high budded on French crab seedlings, measurements were taken just above the union where the tissues were entirely Virginia Crab. For the 62 trees thus grown in closer than orchard stand and budded, at heights ranging from 6 to 52 inches above the ground, the diameter of Virginia Crab trunks ranged from 7/16 inch to 3 4/16 inches, with an average of 1 6/16 inches in diameter. Corresponding diameter of the French Crab seedling trunks, just below the unions, ranged from 8/16 inch to 2 5/16 inches, with an average of 1 6/16 inches in diameter.

These records are not presented as conclusive evidence against the use of Virginia Crab as an unrooted intermediate, but they do indicate that Virginia Crab, which must depend entirely upon French crab seedling roots, does not make its potential growth, that is, the growth which it is capable of making if given an opportunity to develop its own roots. This evidence suggests that Virginia Crab roots play an important part in the vigorous growth of this stock and therefore in the growth of top-worked commercial varieties which make congenial scaffold unions with Virginia Crab.

The Virginia Crab scaffolds developed on the smaller French crab trunks, and roots were less expansive than on own-rooted trees. Sufficient scaffold growth developed, however, to allow an average of four buds per tree of various commercial varieties to be inserted. These buds had grown into branches ranging from 9 to 120 inches in length with the average length about 60 inches. While this might appear to be a sizeable top these trees looked stunted when compared with tops of similar scaffold-worked Virginia Crab trees on their own roots. Subsequent growth records and yield data may change this conception but as viewed at present there is no evidence to substantiate the contention that Virginia Crab as an unrooted intermediate or "stem builder" entirely on a French crab root system will produce the vigorous, healthy trees which are obtained by getting the Virginia Crab onto its own roots.

The Dwarfing Effect of an Intermediate Stem-Piece of Malling IX Apple[1]

By H. B. TUKEY and K. D. BRASE, *N. Y. State Agricultural Experiment Station, Geneva, N. Y.*

IN a previous publication (1) it was shown that the interposition of a 2-inch stem-piece of Malling IX apple between a standard French Crab seedling rootstock and a scion of a vigorous variety resulted in some degree of dwarfing of the entire plant, or stion.

Since the Malling IX rootstock is in itself shallow-rooted and easily broken, the possibility is thus presented of developing dwarf apple trees by this double-working method which are free from these faults. Further, such a method would be economical of Malling IX material, requiring only a short stem-piece rather than an entire rootstock, and suggests a means of meeting the present shortage of Malling IX rootstocks for dwarfing purposes. The results here reported are from an attempt to explore the possibilities and to determine more exactly the effect of a stem-piece of Malling IX used in this way, upon the size, vigor, fruiting, and general characteristics of the stion.

MATERIALS AND METHODS

Double grafts were made during the winter of 1934, using 3-inch piece-roots of French Crab seedlings of domestic origin, 3-inch intermediate stem-pieces of Malling IX scionwood, and 4-bud lengths of the variety scions Baldwin, Delicious, Early McIntosh, and McIntosh (Fig. 1). To obtain good contact great care was taken to select root and scion materials of similar diameter.

As a check and to observe what effect the operation of double-grafting might in itself have upon the stion, similar double grafts were made in which an intermediate stem-piece of McIntosh scionwood was used in place of the Malling IX intermediate stem-piece.

The resulting unions were good and the growth in the nursery was satisfactory (Fig. 1). Bench grafts do not, however, make as much growth as budlings in the western New York area, so that the grafts were grown for two seasons in the nursery before planting in the orchard the spring of 1936. From a number of each variety and combination, four uniform 2-year-old trees were selected and planted in the orchard.

A third series was prepared of single grafts of the same varieties, using French Crab seedling piece roots, and a fourth series was budded on Malling IX layered rootstocks.

Thus comparisons were available between the four scion varieties (a) single-worked on French Crab seedling rootstocks and (b) on Malling IX rootstocks; (c) double-worked on French Crab seedling rootstocks with McIntosh intermediate stem-piece and (d) with Malling IX intermediate stem-piece.

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[1] Journal Paper No. 557, New York State Agricultural Experiment Station, Geneva, N. Y.

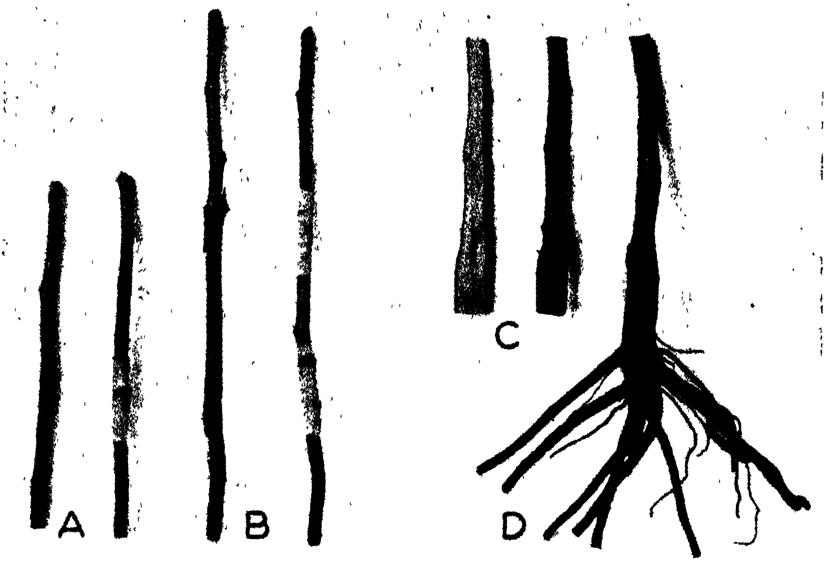

FIG. 1. Method of grafting and material used. A, Single graft before and after tying. B, Double graft before and after tying. C, Longitudinal section of double-grafted two-year-old tree at time of orchard planting, showing union of scion, intermediate stem-piece, and root piece. D, Two-year-old double-grafted tree at time of orchard planting.

RESULTS

Trees grown from bench grafts in the western New York area are not as vigorous and do not make as good growth the first year or two in the orchard as do trees propagated by budding. Propagation by double-grafting is still more difficult so that the number of trees which had to be discarded because of poor growth was greater than would be expected from single-worked or from budded trees. Of the eight combinations listed in Table I, only one includes the full complement of four trees originally planted. The number of trees discarded was greater among combinations which included Malling IX as the intermediate stem-piece than among combinations which included McIntosh as the intermediate stem-piece. Considering the fact that the trees that were planted were selected for uniformity from a larger number of individuals, it is apparent that the method of double-working by bench-grafting has its limitations. It cannot be said that any one factor seems to have been responsible, but the trees which were omitted were smallish, off-color, and generally lacking in tone and vigor. It is not improbable that the difficulties were mechanical, associated with the double grafting.

In Table I are given the height and spread of the trees, the cross sectional areas of the trunks, the year after planting at which the trees first fruited, and the total yield of fruit. Figs. 2, 3, and 4, show representative trees of Delicious, Early McIntosh, and McIntosh with

TABLE I—SIZE AND YIELD RELATIONSHIPS OF SIX-YEAR-OLD APPLE TREES DOUBLE-WORKED ON FRENCH CRAB SEEDLING ROOTS, WITH INTERMEDIATE STEM-PIECES OF MALLING IX SCIONWOOD AND OF McINTOSH SCIONWOOD

Intermediate Stem-Pieces	Number Trees	Average Height (Cms)	Average Spread (Cms)	Average Cross-sectional Area of Trunk (Sq Cms)	Year of First Fruiting*	Average Total Yield of Fruit (Lbs)
			Baldwin			
Malling IX	2	222	174	16.2	7th	9.0
McIntosh	3	288	214	30.0	7th	13.0
			Delicious			
Malling IX	3	274	183	20.7	7th	23.6
McIntosh	4	303	202	31.7	7th	7.7
			Early McIntosh			
Malling IX	3	295	170	27.9	5th	21.9
McIntosh	3	326	174	29.8	5th	13.9
			McIntosh			
Malling IX	2	225	219	14.8	6th	13.7
McIntosh	3	262	198	20.4	7th	12.3

*Because the trees were bench-grafted they were from 1 to 2 years later in coming into bearing than might be expected with budded trees.

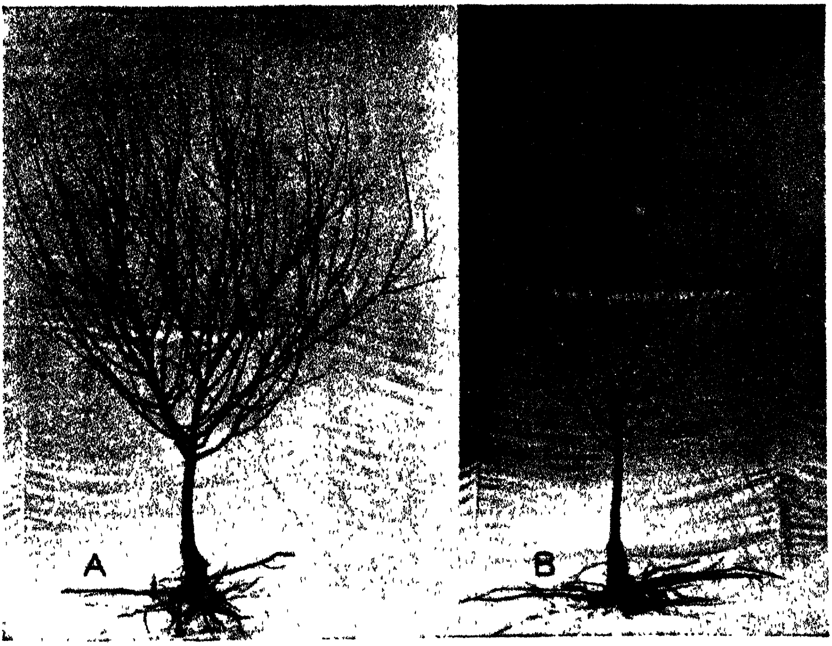

FIG. 2. Six-year-old double-worked trees of Delicious on French Crab seedling roots. A, With intermediate stem-piece of McIntosh scionwood (Delicious/McIntosh/French Crab seedling). B, With intermediate stem-piece of Malling IX scionwood (Delicious/Malling IX/French Crab seedling).

intermediate stem-pieces of Malling IX, in comparison with trees having intermediate stem-pieces of McIntosh.

Size of Tree:—The intermediate stem-piece of Malling IX resulted in all cases in trees less tall than where McIntosh was used as the intermediate stem-piece — approximately 10 to 20 per cent. The spread of the tree was also less, except where earlier fruiting induced by the Malling IX intermediate stem-piece caused the branches to bend downward and outward under the load of fruit. The cross sectional areas of the trunks (Table I) give perhaps the best comparisons of tree size, in which it is seen that the intermediate stem-piece of Malling IX has resulted in Baldwin trees 54 per cent the size of trees having the McIntosh intermediate stem-piece, Delicious 65 per cent, Early McIntosh 91 per cent, and McIntosh 72 per cent. These differences between varieties are of interest.

Fruiting:—The age of fruiting was not materially hastened by the use of the Malling IX intermediate stem-piece as compared with the McIntosh intermediate stem-piece except in the case of the McIntosh variety and there by only one season. The differences in the yield of fruit varied with the variety. Baldwin actually averaged less fruit where the Malling IX intermediate stem-piece was used, and McIntosh yielded only slightly more. On the other hand, Early McIntosh, and especially Delicious, yielded appreciably more when the intermediate stem-piece was Malling IX. Taking into consideration the smallness of the crop, the differences were not large though they favor the trees with intermediate stem-pieces of Malling IX.

Rooting:—The root systems of the trees with intermediate stem-pieces of Malling IX were somewhat smaller and less extensive than trees with intermediate stem-pieces of McIntosh. This would be expected from the generally smaller size of the tops, as already discussed. The influence of the scion variety on the seedling rootstock is noticeable in the decidedly downward nature of the roots of Early McIntosh (Fig. 3), and the more spreading roots of McIntosh (Fig. 4). The trees with intermediate stem-pieces of Malling IX had root systems which were more outward and less downward in spread than when the intermediate stem-piece was McIntosh.

Comparison With Single-Worked Trees:—Table II gives a comparison of (a) double-worked McIntosh trees involving intermediate stem-pieces of Malling IX and intermediate stem-pieces of McIntosh, and (b) single-worked trees on Malling IX rootstocks and on French Crab seedling rootstocks. The trees single-worked on Malling IX rootstocks were much the smallest in height, spread, and cross-sectional areas of trunk. Further, they fruited much the earliest and have borne very much more fruit. At the other extreme, the trees on French Crab seedling roots were the tallest, had the smallest spread, and have borne no fruit. The trees with intermediate stem-pieces stand between these two extremes being less tall, sometimes greater in spread, and having borne some fruit, as discussed in previous paragraphs. As regards stature and performance, however, they were nearer the McIntosh trees on French Crab seedling rootstocks than the McIntosh trees on Malling IX rootstocks.

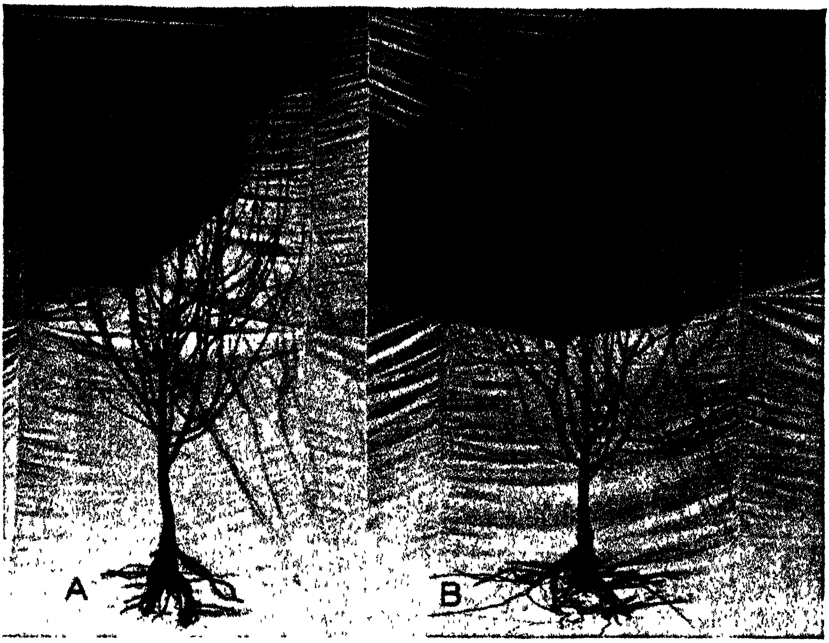

FIG. 3. Six-year-old double-worked trees of Early McIntosh on French Crab seedling roots. A, With intermediate stem-piece of McIntosh scionwood (Early McIntosh/McIntosh/French Crab seedling). B, With intermediate stem-piece of Malling IX scionwood (Early McIntosh/Malling IX/French Crab seedling).

TABLE II—REPRESENTATIVE SIZE AND YIELD RELATIONSHIPS OF SIX-YEAR-OLD McINTOSH APPLE TREES WITH AND WITHOUT INTERMEDIATE STEM-PIECES OF MALLING IX AND McINTOSH SCIONWOOD

Intermediate Stem-Piece and Rootstock	Number Trees	Average Height (Cms)	Average Spread (Cms)	Average Cross-sectional Area of Trunk (Sq Cms)	Year of First Fruiting	Average Total Yield (Lbs)
Malling IX rootstock*	2	192	155	11.3	2nd	71.0
Malling IX intermediate stem-piece and French Crab seedling rootstock	2	225	210	14.8	6th	13.2
McIntosh intermediate stem-piece and French Crab seedling rootstock	3	262	198	20.4	7th	12.3
French Crab seedling rootstock	2	264	184	22.0	?**	0.0

*Four-year-old budded tree.
**Had not yet fruited by seventh year.

Fig. 5 shows the general shape of the single-worked trees. The root system of Malling IX was much restricted and the roots were very brittle and easily broken.

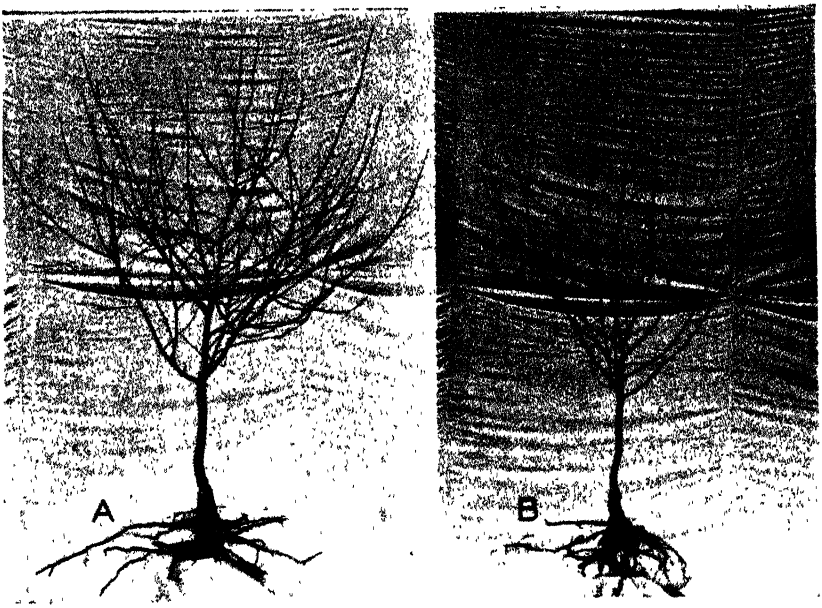

FIG. 4. Six-year-old double-worked trees of McIntosh on French Crab seedling roots. A, With intermediate stem-piece of McIntosh scionwood (McIntosh/McIntosh/French Crab seedling). B, With intermediate stem-piece of Malling IX scionwood (McIntosh/Malling IX/French Crab seedling).

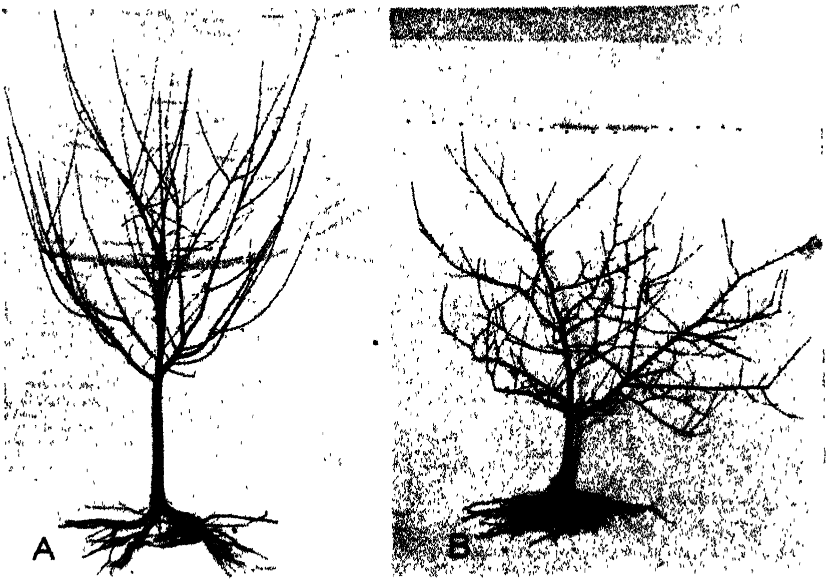

FIG. 5. Single-worked trees of McIntosh, for comparison with Fig. 4. A, Six-year-old McIntosh tree on French Crab seedling roots (McIntosh/French Crab seedling). B, Four-year-old McIntosh tree on Malling IX rootstock (McIntosh/Malling IX).

Discussion

The degree of dwarfing produced by the intermediate stem-piece of Malling IX was not as great as that observed by Knight (1, 2) and by Vyvyan (6), nor as great as was expected from the nursery behavior of double-worked trees reported by the authors in a previous publication (3). The length of the intermediate stem-piece, the nature of the material used, the general soil and climatic conditions, or other factors may well have exerted modifying influences. Yet, in general, the results are in agreement in that the intermediate stem-piece of Malling IX has resulted in smaller and earlier-fruiting trees than are produced by either double-working with an intermediate stem-piece of McIntosh or by single-working on French Crab seedling rootstocks.

At the same time the single-working on Malling IX has produced decidedly the smallest and earliest fruiting trees in the tests. It is apparent, therefore, that the stem-piece or the union do not alone bring about the dwarfing and early fruiting observed when trees are propagated upon the Malling IX rootstock, but that the Malling IX root itself clearly plays an important part (6).

While a smaller and earlier fruiting than standard fruit tree may be produced by the double-grafting method, employing a 3-inch intermediate stem-piece of Malling IX scionwood, the same degree of dwarfing and of early fruiting can be more easily and accurately accomplished by the use of some other of the Malling rootstocks, as Malling VII, IV, II, V, or I (4, 5). The handicaps of brittleness and easy-breaking of the Malling IX root are avoided by the double-working method, but this, too, can be accomplished by single-working on the rootstocks above enumerated. Further, the double-grafting method has definite limitations in the western New York nursery area in that such grafts are difficult to make and are much slower growing and less vigorous than budded stock.

Conclusion

The interposition of a 3-inch stem-piece of Malling IX scionwood between the scion variety and the French Crab seedling rootstock, using a double graft, resulted in 6-year-old trees which were smaller and earlier fruiting than standard trees composed of similar scion varieties worked upon French Crab seedlings using a single graft. Yet they were only slightly smaller and slightly earlier in fruiting than double-worked trees employing an intermediate stem-piece of McIntosh scionwood instead of Malling IX scionwood. Trees single-worked on Malling IX rootstocks were decidedly smaller and earlier in coming into fruiting than trees produced by double-grafting with an intermediate stem-piece of Malling IX rootstock.

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The Influence of Substituted Groups in Some Plant Growth Substances on Rooting Responses of Cuttings[1]

By V. T. Stoutemyer, *U. S. Department of Agriculture, Glenn Dale, Md.*

AFTER a variety of indolyl, naphthyl and phenyl compounds were demonstrated to be active growth substances, experimenters noticed that certain species of plants responded better to a particular compound or group of compounds than to others. For example, naphthyl acetic acid produces heavier rooting of cuttings of privet than indolyl growth substances. The author (1, 2) has shown that cuttings of some plants root better with the growth substances applied in the form of amides than with the free acids. On the other hand, some species respond in the opposite manner, and still others exhibit no preferential responses. In the present study, divergent responses were obtained in the rooting of cuttings following slight changes in composition or structural configuration of growth substances.

Position of Methyl Group on Ring

The change of position of a methyl group from the two to the four position on the ring has been found to influence the rooting response of certain species of plants. In the experiment to be recounted, six replications of 20 cuttings each were used for each treatment and were placed in random arrangement in blocks. All cuttings were treated by applying talc to the base of the cuttings either alone or in combination with a growth substance in the proportion of 1 part of the latter per 1000 parts of talc. In some of the first trials, the mixtures were prepared on the basis of equivalent molecular weights, but the corrections were so slight that this was abandoned and the mixtures were prepared on the basis of equal weights. The cuttings were counted and graded by classes according to the heaviness of rooting, and the roots were removed, oven dried and weighed on a chemical balance. The percentages of rooting and the dry weights of the roots are presented in Table I and the data on the latter were subjected to analysis of variance.

The data in Table I show that the change in position of the methyl group produced in virtually all cases highly significant differences in the heaviness of rooting, and that both the acids and amides were affected by the change. The results also at least suggest that some relationship exists between these differences and those previously demonstrated for acid and amide growth substances. Thus with the species which rooted better with naphthyl acetamide than with alpha naphthyl acetic acid, the 2-methyl naphthyl 1-acetic acid produced heavier rooting than the corresponding 4-methyl compound. In such cases, the 4-methyl naphthyl 1-acetamide produced heavier rooting than the 2-methyl naphythl 1-acetamide. Examples of this are *Euonymus japonica L.* and *Pachysandra terminalis* Sieb. and Zucc. It will be noticed in one case with the latter subject that the 2-methyl naphthyl 1-acetic acid produced heavier rooting than the naphthyl acetamide although the latter was more effective than the alpha naphthyl acetic acid.

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[1] These investigations were conducted as cooperative research by the Hillculture Division, Soil Conservation Service and the Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture, with the object of developing methods of propagation of various plants including those of exceptional difficulty and those of importance in hillculture and soil erosion control plantings. Thanks are due to Mr. F. L. O'Rourke of the Hillculture Division for assistance with certain phases of the investigation. The growth substances used in these experiments were obtained from the American Chemical Paint Company, Ambler, Pennsylvania.

With *Pyracantha coccinea* Roem. rooting was heavier with the naphthyl acetic acid than with the amide and the 4-methyl naphthyl 1-acetic acid produced heavier rooting than the 2-methyl compound. In view of the relationship shown above, the 2-methyl naphthyl 1-acetamide might be expected to produce heavier rooting than 4-methyl naphthyl 1-acetamide. This appears to be the case with *Pyracantha.*

TABLE I—INFLUENCE OF POSITION OF METHYL GROUP ON ROOTING OF CUTTINGS (WEIGHT OF ROOTS IN MILLIGRAMS)

Species and Rooting Period	Talc	Naphthyl Acetic Acid	4-Methyl Naphthyl 1-Acetic Acid	2-Methyl Naphthyl 1-Acetic Acid	Naphthyl Acetamide	4-Methyl Naphthyl 1-Acetamide	2-Methyl Naphthyl 1-Acetamide	Minimum Difference for Significance (1 Per Cent Probability)
Euonymus japonica L. (33 days)								
Weight of roots	585	705	726	1,241	1,059	922	777	85
Per cent rooted	72	73	69	80	72	74	68	
Pachysandra terminalis Sieb. and Zucc. (38 days)								
Weight of roots	167	452	869	1,874	990	1,411	936	47
Per cent rooted	63	96	93	98	71	96	87	
Pachysandra terminalis Sieb. and Zucc. (44 days)								
Weight of roots	506	2,446	1,765	2,953	3,822	3,131	1,814	153
Per cent rooted	75	93	91	95	98	97	88	
Pyracantha coccinea Roem. (30 days)								
Weight of roots	745	839	1,125	843	717	728	906	25
Per cent rooted	87	83	88	84	73	72	86	

Serious deterioration of the effectiveness of growth substances mixed with talc may take place under certain conditions of storage in less than a year. In view of possible changes of stability or volatility with the introduction of the methyl groups, the preparations shown in Table I were stored for 6 months and tested in comparison with freshly made mixtures. In no case was the slightest decline in root forming response noticeable, which indicates that these compounds are reasonably stable.

THE ISOPRENE ESTER OF NAPHTHYL ACETIC ACID

The esters and salts of growth substances are recognized to be quite similar to the free acids in effectiveness. The isoprene ester of naphthyl acetic acid has been particularly effective in comparative tests, which in the following instances were usually made with two duplicate lots in each treatment. Each lot had 20 cuttings. The control lots were treated with talc at the bases, and growth substances were applied to the others as 1–1000 mixtures in talc, except in the case of *Cornus florida* Linn. in which a 1–250 concentration was used. The cuttings were rooted in sand in a greenhouse with a centrifugal atomizer for humidification which has been described previously (3). The cuttings were graded in groups based on number and length of roots. The results are presented in Table II.

TABLE II—INFLUENCE OF ISOPRENE GROUP ON ROOT FORMATION IN CUTTINGS

Species	Rooting Period (Days)	Per Cent Rooted							
		Talc		Naphthyl Acetic Acid		Naphthyl Acetamide		Isoprene Ester of Naphthyl Acetic Acid	
		Total	Heavy	Total	Heavy	Total	Heavy	Total	Heavy
Actinidia arguta (Sieb. and Zucc.) Miq.	23	70	15	93	40	93	33	98	33
Cornus florida L	40	68	13	90	28	83	30	95	75
Cyrilla racemiflora L	45	53	8	38	5	60	35	80	53
Jasminum fruticans L	56	88	40	78	15	100	40	90	45
Ligustrum Quihoui Carr	33	92	18	96	17	97	51	98	33
Neillia longiracemosa Hemsl	29	58	0	70	0	78	8	83	23
Stewartia pentagyna L'Her	91	13	3	23	5	70	45	43	15

In various tests which were made with the isoprene ester of naphthyl acetic acid, the ester often appeared to produce superior rooting, particularly in regard to heaviness. These comparisons were made on an even weight basis and an adjustment for the weight of the isoprene group would have intensified the advantage of the ester even more. The data appear to show that the isoprene group generally aids rooting. The promising responses obtained with the isoprene ester of naphthyl acetic acid suggest that studies should be conducted with other compounds containing this group.

TETRA-HYDRO-NAPHTHYL ACETIC ACID

In a previous report (2) some data was presented to show that 1, 2, 3, 4 tetra-hydro-naphthyl acetamide was a highly effective growth substance in comparison with alpha naphthyl acetic acid and was apparently even superior with some subjects. The growth substances were applied as mixtures of 1 part of growth substance per 1000 parts of talc. No adjustment was made for the slightly higher molecular weight of the tetra-hydro-naphthyl acid in these tests because of the very slight discrepancy between the two bases of comparison. The data are shown in Table III and the results were subjected to analysis of variance. The results of this test indicate that the inclusion of the hydrogen groups on the ring did not diminish the action of the growth substance, and that significant increases in rooting were produced with some cuttings.

TABLE III—INFLUENCE OF TETRA-HYDRO-GROUPS IN NAPHTHYL ACETIC ACID ON ROOT FORMATION IN CUTTINGS

Species	Rooting Period (Days)	Per Cent Rooted			Dry Weight of Roots (Milligrams)		
		Talc	Alpha Naphthyl Acetic Acid	Tetra-hydro Naphthyl Acetic Acid	Talc	Alpha Naphthyl Acetic Acid	Tetra-hydro Naphthyl Acetic Acid
Euonymus japonica L.	33	72	73	64	585	705	705
Pachysandra terminalis Sieb. and Zucc.	38	63	96	93	167	452	1,634*
Pachysandra terminalis Sieb. and Zucc	44	75	93	96	506	2,446	3,001*
Weigela floribunda (Sieb. and Zucc.) C. A. Mey.	20	83	87	95	789	1,785	2,927*
Weigela floribunda (Sieb. and Zucc.) C. A. Mey	18	78	85	89	664	1,055	1,331*

*Exceeds level of significance (1 per cent probability).

DISCUSSION

The addition of methyl, hydrogen or isoprene groups in various positions on a growth substance did not interfere with the action in aiding root formation and may even enhance it in some cases. The marked differences in rooting response reveal the existence of some fundamental differences which are inherent in the physiology of different plants. Some definite groupings of plants may be made on the basis of varying responses in root formation with various compounds. When these are developed sufficiently, some important facts concerning the nature of growth substances may be disclosed.

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The Effect of Indole-Butyric Acid in Talc on Rooting of Softwood Cuttings of Blueberries

By F. L. O'Rourke, *Soil Conservation Service, Glenn Dale, Md.*

PRELIMINARY tests at this station showed that indole-butyric acid was the most effective of the commonly used synthetic growth substances in promoting rooting of softwood cuttings of *Vaccinium australe*. Doran (2) reported that indole-butyric acid in aqueous solution increased rooting in softwood cuttings of several commercial varieties. The present study was undertaken to test the effectiveness of this substance in talc dust. The methods of preparation and application have been described by Stoutemyer (3).

Softwood cuttings collected from a large number of native wild blueberry plants of this species were well mixed, treated in lots of 20, and the lots randomized as to position. On June 11 they were set in a bench of washed river sand in a lean-to greenhouse with northern exposure. Table I shows the rooting at the time the cuttings were removed on August 3.

TABLE I—Rooting Response of Softwood Cuttings of *Vaccinium australe* to Indole-butyric Acid in Talc

Treatment	Number Set	Total Rooted	Degree of Rooting		
			Heavy	Medium	Light
Control	100	14	1	7	6
Talc only	100	21	3	6	12
Indole-butyric acid in talc 1 mg/g	100	63	33	15	15

Analysis of variance showed the difference in number rooting to be well above the 1 per cent level of significance. In addition to increasing the total number rooted, the indole-butyric acid treatment produced greater masses of roots on the individual cuttings. While the rooting percentages may not appear high, the differences due to treatment are pronounced and truly show the effectiveness of the growth substance in this species.

The same substances were tried in a preliminary way on smaller lots of softwood cuttings of other blueberry species with comparable results, as shown in Table II. With the exception of *Vaccinium ashei* and *V. australe*, the author is not aware of any published reports of the rooting of these species from softwood cuttings. Clonal material was used for *V. angustifolium*, *V. atrococcum*, and *V. australe*, but for the other species cuttings were collected from mature plants of seedling origin. Twenty cuttings were used in each treatment, except for *V. pallidum* and *V. atrococcum* in which 40 were used throughout. The cuttings from these various species were not taken or set at the same time, but all the cuttings of each individual species were collected, made, treated, and set on the same day. The nomenclature used is that of Darrow, Camp, Fischer, and Dermen (1).

While the numbers used in each species were comparatively small,

TABLE II—ROOTING RESPONSE OF SOFTWOOD CUTTINGS OF SEVERAL *Vaccinium* SPECIES TO INDOLE-BUTYRIC ACID IN TALC

Species	Rooting (Per Cent)				
	Control	Talc Only	Indole-butyric Acid in Talc		Rooting Period (Days)
			1 Mg/G	4 Mg/G	
Vaccinium angustifolium Ait.	20.0	25.0	40.0	—	54
Vaccinium ashei Reade	35.0	—	60.0	—	50
Vaccinium atrococcum (Gray) Heller.	30.0	33.0	30.0	65.0	52
Vaccinium australe Small	10.0	25.0	50.0	—	59
Vaccinium pallidum Ait	27.5	37.5	55.0	—	65
Vaccinium pallidum Ait	0.0	15.0	32.5	47.5	50

the results appear consistent enough to justify the use of indole-butyric acid in talc on softwood cuttings of the species mentioned insofar as the material used is representative of the species.

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The Effect of Length of Root, Size of Top and Watering at Planting on the Growth of Aleurites fordii

By JOSEPH HAMILTON, *U. S. Department of Agriculture, Gainesville, Florida*

UNLIKE some other plants, the tung tree, *Aleurites fordii* Hemsl., can be transplanted from the nursery to the orchard with consistent success even under somewhat adverse conditions. In the Gainesville, Florida, area the usual practice when digging nursery trees is to cut the roots at a depth of 12 to 18 inches, and on a radius of 6 to 12 inches from the trunk. When planted in the orchard the top is cut back to 6 inches above the ground line. Only one bud is allowed to grow, which produces the trunk with development of lateral framework branches usually towards the end of the first growing season. Such trees under favorable conditions usually make a vigorous growth the first season in the orchard. Transplanting of trees with tops not cut back is favored by a few growers, but the practice is generally reported to give a poor stand, and, if the trees live, to result in less growth than when the trees have been pruned back to short stubs. Painter and Sharpe (2) obtained promising results with unpruned transplants but their tests were conducted on an exceptionally favorable soil. Rather extensive observation indicates that there are wide differences in the performance of transplanted trees that can not be accounted for by variation in soil and seasonal conditions alone. An experiment was set up to determine the effects of cutting back the tops or roots, or both, and of watering the trees at time of transplanting to compact the soil around the roots. The treatments were as follows:

A. Tops and roots severely pruned. Trees dug with roots cut at a depth of 12 to 18 inches and on a radius of 6 to 12 inches from the trunk. Tops cut back at planting to 6 inches above the ground line. This treatment was carried out by the labor force of the plantation where the experiment was conducted and is representative of the usual digging and planting practices.
B. Trees handled in exactly the same manner as A but the tops left intact.
C. Trees especially dug with practically the entire fibrous root systems intact. This was accomplished by digging as much as 4 feet deep and 2 feet out from the tree. It required about ½ hour to dig one of these trees. The tops were pruned off as in treatment A.
D. Trees dug in a manner identical with group C but the tops not pruned off.

In each replication each treatment was used on a plot of four trees. There were five replications. A split plot design was used in which two trees of each plot were planted without watering and the other two were watered well when planted.

Admittedly these treatments represent extremes which were used to determine whether or not root and top pruning affect the subsequent growth of the transplanted tree, and were not designed to indicate desirable practices in commercial operations. The holes in which the long-rooted trees were planted were approximately 3 feet in diameter and 3 feet deep. The short-rooted trees were planted in holes somewhat over 1 foot in diameter and 1 foot deep. In planting operations the trees were carefully handled to avoid drying out the fibrous roots. The planting was done March 26 and 27, 1942, previous to the time of bud break. The trees used were uniformly of a low-headed type having been grown from self-pollinated seed from a single parent tree. The diameter of the trunks at 4 inches above the ground line was measured and each tree was weighed before and after pruning. These data are given in Table I.

TABLE I—Effect of Pruning Tops and Roots on Mean Weight of Trees and Proportion of Weight Lost in Transplanting (Gainesville, Florida, March, 1942)

Treatment (Parts Pruned)	Weight at Digging (Ozs)	Weight at Planting (Ozs)	Loss in Weight in Digging and Planting		
			Tops (Ozs)	Roots (Ozs)	Whole Tree (Per Cent)
A. Tops and roots .	27.6	16.0	8.3	14.5*	59*
B. Roots only . .	29.2	25.7	—	13.1*	34*
C. Tops only . .	39.9	28.7	11.2	—	28
D. None . . .	37.7	37.7	—	—	0

*Estimate based on mean weight of similar trees in treatments C and D.

It is considered that the trees in treatments C and D were dug with the root system practically intact. Any roots actually cut off during digging were so small that they probably would have died in transplanting. The data show that approximately half of the total weight of the tree is lost when transplanted by the methods usually followed in Florida.

The effect of the treatments on mortality is shown by the data in Table II. The trees of treatment D pushed out their buds before those of any other treatment and gave evidence that there would be very little setback in transplanting. The buds on trees of treatment B were last to break and many of the tops died. These dead tops were cut off on April 28 to force out a shoot from the base. In some cases removal of the top failed to save the tree.

None of the trees died excepting those having whole tops and short roots. This supports the opinion held by many growers that transplanting trees without cutting back the tops is unsatisfactory. However, the survival of all trees having unpruned tops and long roots indicates that the mortality and poor growth are due to an inadequate root system. Evidently so far as survival is concerned water was not a limiting factor except in treatment B in which the transplanted trees had short roots and unpruned tops. There is some indication that in this treatment, watering increased the number of trees that survived ($X^2 = 3.23$, 5 per cent = 3.84).

TABLE II—RELATION OF PRUNING AT PLANTING ON MORTALITY OF TUNG TREES (GAINESVILLE, FLORIDA, 1942)

Treatment (Parts Pruned)	Sub-treatment	Number Total Trees	April 28, 1942		October 19, 1942 Number Trees Dead
			Number Top and Roots Alive	Number Top Dead and Roots Alive	
A. Tops and roots	Watered	10	—	—	0
	Not watered	10	—	—	0
B. Roots only	Watered	10	3	7	2
	Not watered	10	0	10	7
C. Tops only	Watered	10	—	—	0
	Not watered	10	—	—	0
D. None	Watered	10	10	0	0
	Not watered	10	10	0	0

At the beginning of the season, trees with the tops pruned back, but with long roots, made distinctly more growth than those with both tops and roots pruned. In the latter part of May many of the trees in the experiment were severely affected by copper deficiency which resulted in stunted and misshapen tops and dieback of many shoots. The symptoms of copper deficiency had not previously been recognized and it was not until midsummer that the cause was ascertained (1). The trees were then treated and normal foliage again developed. The new growth of all the trees was adversely affected by the copper deficiency which also affected in an abnormal manner the reheading of trees with tops pruned. This effect of course could not be present in the group of trees planted with tops unpruned, as they carried the branches developed in the nursery.

The cross-sectional area of the trunks of the trees was determined on October 19 and the mean increase over the original size is shown by the data in Table III. At the end of the growing season it was obvious that the size of the root system and the cutting back of the top have a tremendous influence on whether or not the tree develops satisfactorily the first year. An analysis of variance of the gains in cross-sectional area of the trunk for treatments A, C and D gives an F value of 30.00 for treatments where 8.65 is required at the .01 level.

There appears to be a relation between the initial weight of the trees in treatment D, and their gain in cross-sectional area at the end of the

TABLE III—INFLUENCE OF PRUNING AT PLANTING ON MEAN GAIN IN CROSS-SECTIONAL AREA OF TRUNK OF TUNG TREES PLANTED MARCH, 1942 AT GAINESVILLE, FLORIDA (RECORDS MADE OCTOBER 19, 1942)

Treatment (Parts Pruned)	Watered at Planting (Sq Cm)	Not Watered at Planting (Sq Cm)	Average (Sq Cm)
A. Tops and roots	4.39	4.15	4.27
B. Roots only	—	—	—
C. Tops only	5.99	7.64	6.82
D. None	14.21	13.35	13.78
Average	8.20	8.38	—

first season. The within-block regression is significant as is the correlation coefficient (r = .55). Since only a part of the variation due to soil is removed by the within-block calculation it is probable that the correlation between the weight of the trees at transplanting and the gain in cross-sectional area would be somewhat higher had they been planted on a strictly uniform soil. This relation was not found to exist in the treatments in which the tops of the trees were cut back.

The customary method of transplanting gave satisfactory results, but trees transplanted with their tops and roots intact made a significantly larger increase in size of trunk. Further trials are required to determine whether a method for transplanting unpruned trees can be worked out for commercial practice. If this were possible larger, earlier and heavier bearing orchard trees could be obtained in less time than is possible with the usual transplanting methods, and in addition the well-spaced and wide-angled branches formed in the nursery could be preserved.

The writer is glad to acknowledge the assistance of Fred W. Burrows in carrying out much of the field work of these experiments.

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Growing and Transplanting Nursery Trees of Aleurites montana in Florida[1]

By Joseph Hamilton, *U. S. Department of Agriculture,* and
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OF THE genus *Aleurites* the species *fordii* has become well established throughout the tung belt of the southern United States but as yet commercial production from the species *A. montana* (Lour.) Wils. is confined to somewhat tropical areas of foreign countries. The tree of the latter under native conditions appears to be much longer lived, is larger and makes more vigorous growth than *Aleurites fordii* (3, 4, 7). The quality of its oil is reflected by price is about equal to that from *A. fordii* with which it is often blended (3, 5).

Aleurites montana has three important characteristics which have retarded its establishment in this country. (a) There has often been difficulty in obtaining a good stand of trees in the nursery and in establishing them in the orchard. (b) The species is monoecious (7) but in seedling orchards a rather large proportion of the trees are either predominantly staminate or pistillate in flowering habit. This condition may be corrected by budding most trees to pistillate types, and a few to staminate types for use as pollinizers. (c) It is considerably more tender to cold than *A. fordii.* However, the climate of south and central Florida is very similar to that of the part of Indo-China in which Reteaud (6) obtained optimum results in trial plantings. A total of five mature trees are now thriving at Gainesville and Orlando, Florida.

Aleurites montana merits thorough testing. In Florida it offers three main possibilities: (a) It is easily crossed with *fordii* and it may be possible to incorporate some of the desirable characters of each species in the hybrids. (b) As has been pointed out, large areas of Florida appear to be suited climatically to *A. montana,* and it is worthy of trial as a new crop in local areas where horticultural crops of higher values do not succeed. (c) It may be used as a stock for *A. fordii,* as has been found advantageous in certain foreign areas (1, 5, 7).

During 1933 the Florida Agricultural Experiment Station produced a satisfactory stand of trees in a nursery on moist soil at Gainesville, but in general, other plantings, which have been made on dry soil, have not given satisfactory stands. In February 1941, the junior author and Dr. Walter Reuther initiated the investigation now reported by making five small plantings of seed at various points throughout the state. These resulted in a high percentage of germination, but final stands were only 5 to 15 per cent and there was very poor growth of the few trees that did survive.

Experimental Procedure

As the previous work had shown propagation under Florida conditions to be one of the most difficult problems in connection with

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[1] The authors appreciate the cooperation of Dr. J. R. Beckenbach and his staff of the Vegetable Crops Laboratory, Bradenton, Florida, without which it would have been impossible to conduct the nursery experiment reported.

Aleurites montana development, an experiment to determine the effect of time and depth of planting, with and without a mulch, was laid out on land at the Vegetable Crops Laboratory at Bradenton, Florida. Plantings were made on four dates: December 5, 1941, January 20, February 20, and March 20, 1942. A part of the planting was covered with a dry weed mulch intended to maintain soil moisture and temperature at levels suitable for young plants, and a part was left uncovered. Seed from two trees was used; SM–1–1 a relatively small pistillate-flowered tree on the Experiment Station grounds at Gainesville, and SM–8–1 a large pistillate-flowered tree on the United States Sub-Tropical Station grounds at Orlando, Florida. Two planting depths were used: shallow, covered by approximately 2 inches of soil; and deep, covered by approximately 4 to 5 inches of soil. Each planting treatment comprised 50 seeds from each parent tree.

RESULTS

Growing Seedlings:—The seed planted December 5 had sprouted but had not emerged on January 20. From 100 SM–8–1 seeds planted on December 5, without mulch, including both deep and shallow lots, 73 young plants, each 4 to 6 inches high, were in active growth on February 20. What appeared to be a fungus was observed on the stems of a number of the seedlings and 10 were so damaged that they seemed to have no chance of survival. There were relatively large dark lesions along the stems and development was arrested in the affected area; this resulted in crooked rather than erect growth. By March 20 at least 78 plants had emerged, of which 33 were seriously affected; but when examined on May 7, 63 of the 78 trees were still alive. The lesions had dried up and no longer appeared to be injurious. As the plants were suffering from drought at this time, it is unlikely that all of the 15 trees which died were killed by the disease. If this trouble is of fungus origin, control measures may eventually have to be developed, but in this trial natural recovery of most plants was finally made.

The weed mulch evidently lowered the soil temperature and retarded germination of the seed under it, as none had emerged by February 20. By March 20, the mulched plots had developed a fair stand of plants which seemed slightly less crooked and damaged than those in unmulched plots.

In previous trials a large number of plants had been affected during May by desiccation, wilting, and necrosis of the stem immediately above and at the ground level, soon followed by the death of the whole plant. A characteristic symptom is the necrotic condition of the stems while the tops above the dead zones appear wilted to varying degrees. When observed in earlier trials this condition was tentatively classed as a "sand burn". In the 1942 nursery it was observed to some extent on May 7 associated with dry soil areas but not with those still obviously moist. It is clearly evident that these symptoms are the reaction of *Aleurites montana* to deficiency of soil moisture. This trouble is not to be confused with the so-called disease observed in the early spring. Between May 7 and May 27 the mortality was severe but was no doubt partly arrested by an irrigation of May 11 and rain of May 12. The plants continued to die between May 27 and July 25, but thereafter practically all survived.

Effects of soil moisture on survival of *Aleurites montana* seedlings are shown by counts of live plants for the entire nursery, which included a considerable number of other trees in addition to the experimental planting. These counts are as follows: May 7, 1272; May 27, 1192; July 25, 981. Effective rainfall in April and May consisted of 3.33 inches on April 16–17 and 2.13 inches on May 12–13. As the one irrigation immediately preceded a rain, it was probably of little benefit. There was a good rain June 1 and no drought thereafter. Of the rather large number of trees lost between May 27 and July 25 many probably died early in the period, being unable to recover from the drought extending to June 1.

Table I gives data for the number of trees living by lots and their mean height on July 25 in the nursery experiment described above.

TABLE I—NUMBER OF LIVE SEEDLINGS OF *Aleurites montana* AND THEIR MEAN HEIGHT, JULY 25, 1942, BRADENTON, FLORIDA (50 SEEDS PLANTED IN EACH LOT)

Parent Tree and Treatment	Date of Planting							
	Dec 5, 1941		Jan 20, 1942		Feb 20, 1942		Mar 20, 1942	
	Number Alive	Height (Inches)	Number Alive	Height (Inches)	Number Alive	Height (Inches)	Number Alive	Height (Inches)
SM-8 1:								
Mulched								
Deep planting	30	22 0	22	16.0	6	7.3	10	9.5
Shallow planting	28	23.8	4	9.0	1	7.0	14	10.7
Not mulched								
Deep planting	29	13.2	27	17.9	20	11.0	17	6 4
Shallow planting	24	15.8	18	11.8	7	11.0	19	8 1
SM-1-1:								
Mulched								
Deep planting	29	17 7	22	15.1	14	5.6	7	5.3
Shallow planting	22	12.2	10	8.2	3	6.0	2	8.0
Total	162	—	103	—	51	—	69	—
Mean	—	17.4	—	13.0	—	8.0	—	8.0

The two early plantings gave reasonably good stands of trees and good growth. On July 25 there were 162 trees of an average height of 17.4 inches from the December 5 planting and 103 trees of an average height of 13.0 inches from the January 20 planting. Owing to poor stands and small size of trees, the two late plantings were of no practical value. Both deep and shallow plantings in December gave good results, but only deep planting in January resulted in a satisfactory stand and size of trees. No frost was reported on this site in 1941–42. In areas where frost damage is likely to occur planting should be deferred until January and the seed should be planted deeply. Mulching delayed germination and appears to be of no value. It was particularly disastrous to seeds planted shallow in January. There were no striking differences between the seed from the two parent trees as regards germination, number surviving, or growth of seedling trees.

The factors studied should all be considered in relation to their effect on development of a plant able to withstand the usual spring drought in Florida. It is clear that the plants starting earliest in the season were very little damaged by drought presumably because their root systems were larger and deeper than those of plants starting later. It should be noted that where the stand of trees was poor their growth was also poor. This indicates that they do not quickly recover from unfavorable conditions. All the plants had sufficient moisture after June 1, but the stunted seedlings from late plantings never attained a state of vigorous growth.

Budding:—As *Aleurites montana* is reputed to be a more vigorous grower than *A. fordii*, it was considered possible to bud the former in midsummer, force the buds as soon as they had set, and obtain a suitable budded tree in one season. On July 9, a number of buds of *fordii* and *montana*, were set in *montana* seedlings using the inverted-T method. The bud was cut from the scion according to the Forkert method (1). Buds were tightly wrapped with No. 516 budding strips. Practically all buds lived. On July 25 the stocks were cut off to force the buds. This treatment killed most of the trees. Early budding of young seedlings has proven unsatisfactory with *A. fordii* and it now seems unlikely that better results will be obtained with *montana* unless more vigorous early growth can be induced. A series of buds of *fordii* and *montana* put in September 17 and 18 to be forced in the spring of 1943 took well.

Since some of the trees in the nursery propagation experiment above reported were among those budded July 9 and later killed in attempting to force it was necessary to terminate the experiment with counts and measurements of July 25. However, several random lots of trees, representing different soil conditions in the nursery, grown from seed planted in December and January, but not all in the nursery experiment, were measured July 25 and again on October 5. The data are given in Table II.

Probably due to crowding, there were a few runts in each lot which brought down the October average height of the trees possibly as much as a foot. The major portion of the total growth of the trees was made in August and September. The high correlation coefficients show that

TABLE II—RELATION OF EARLY SEASON GROWTH TO LATE SUMMER GROWTH OF *Aleurites montana* SEEDLINGS (BRADENTON, FLORIDA, 1942)

Lot	Number of Trees	Mean Height July 25th (Inches)	Mean Gain in Height July 25th to October 5th (Inches)	r
A	10	8.2	12.2	0.96
B	8	8.1	24.5	0.97
C	21	12.0	23.0	0.76
D	24	19.5	41.2	0.62
E	27	12.0	26.2	0.66
All trees .	90	13.2	27.6	0.69*

*Within lots, calculated according to Goulden (2).

the trees large early in the season are large at the end of the season and, conversely, small trees remain small. Trees that do not enter their main period of growth in a good thrifty condition rarely attain a satisfactory final size.

Transplanting the Trees:—Transplanting to the orchard of *Aleurites montana* trees of different ages and sizes has been accomplished. Very satisfactory results were obtained with thrifty 1-year-old seedling trees which were transplanted early, with a relatively large part of the root system dug with the tree, and watered often enough to prevent wilting. Where the trees suffered from lack of soil moisture due to droughty soil or infrequent watering, many died and those surviving did not make satisfactory growth.

CONCLUSIONS

Aleurites montana seed should be planted in December or January, on good moisture-retaining soil and in frost free locations, and irrigated if necessary. If all these conditions cannot be met in specific cases, planting late enough to avoid frosts and irrigating frequently during dry periods should produce satisfactory seedlings. *A. fordii* has been satisfactorily budded on *A. montana* in September using the inverted-T method. These buds have not yet been forced out. Trees similar in development to the usual *A. fordii* seedling nursery tree have been successfully transplanted to orchard locations.

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Rootstocks for Grapes in the South[1]

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FOR decades the history of southern "bunch" grape growing has been a record of tragedies, and it is only within the last 60 years that much progress has been made. The first attempts were largely efforts to grow the vinifera grapes of Europe, and even though these varieties were under the care of expert European vineyardists, the efforts resulted in total failure. Later efforts were made to grow varieties of American origin. These were mainly labrusca and labrusca-vinifera hybrids from the northern United States. They did somewhat better than the pure vinifera type but they were not successful. Today almost the only grapes successfully grown in the far South are varieties that originated, all or in part, from native southern species, although the use of adapted rootstocks has made it possible to grow a few of the northern labrusca and labrusca hybrids that fail on their own roots.

Various rootstocks have been tried and many have been found helpful in prolonging the life and increasing the vigor and yield of the vines; very little published information, however, is available. In an effort to learn just what stocks are best adapted, a survey was made through the horticultural departments of the southern colleges and experiment stations, certain county agricultural agents, and vineyardists. The response was most generous and wholehearted and a great deal of information was received. A few States are doing extensive research, others are conducting small-scale experiments, and many valuable observations have been made. The purposes of the work vary from ease of propagation to increased production, increased longevity, phylloxera resistance, nematode resistance, early fruit maturity, and other desirable qualities. Thus work done in the various sections is not entirely comparable. Consequently, a brief resumé of the work will be given before an attempt is made to summarize it.

Of eight stocks tested in South Carolina, Dog Ridge, Rupestris St. George, and Lukfata have been the most resistant to nematodes or the least injured, and have been most effective in increasing the vigor, length of life, and yield of the vines.

In Georgia, 29 stocks have been tested and of these, Dog Ridge, Champanel, and Lukfata are outstanding in their benefits to the scions and especially in increasing the life and vigor of the scion varieties which they bore.

In Florida the short life of the vine has been a limiting factor in the commercial production of grapes, which, because of the early season, bring an excellent price; consequently, numerous stocks have been tried. At the present time Marguerite, R. W. Munson, and Lukfata are in favor, and Champanel has been considered to be a good stock. At one time Extra, Herbemont, and *Vitis champini* were widely used (2).

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[1] Grateful acknowledgment is made of the generous response of those interested in grape growing in the South who contributed the information contained in this paper. Those men are the real authors.

An extensive test of ungrafted stock vines made at Poplarville, Mississippi (4), showed that the following varieties were the longest lived and most vigorous: Barnes, Joly, *Vitis monticola* x *V. rupestris,* Ramsey, *V. riparia* x *V. berlandieri,* No. 161–49, Rupestris St. George, De Grassett, Dog Ridge, and *V. monticola* x *V. riparia,* No. 18804.

At Meridian, Mississippi, where 10 rootstocks were tested, Dog Ridge was greatly superior to the other stocks in the beneficial effect upon the scion and also superior to own-rooted vines (3).

In Texas, as the result of considerable work, Dog Ridge, La Pryor, and Champanel are considered the most useful.

In Oklahoma, a number of unspecified rootstocks were used with beneficial results, especially in increasing the production of weak-growing varieties such as Campbell Early and Moore Early. For sandy soils the Jacques, also known as Lenoir, has proved to be very good.

Similar beneficial results on growth and production are noted in Arkansas, especially in the case of Concord, Campbell Early, and Moore Early when these three are grafted on Cynthiana, or on Wine King. Some of the stocks tested increased the size and number of fruit clusters (1) and many of them altered the composition of the fruit (5).

The Missouri State Fruit Experiment Station at Mountain Grove has secured great benefits in yield and vigor from many different rootstocks, especially Constantia, *Vitis riparia* x *V. rupestris,* No. 3309, and *V. cordifolia* x *V. riparia,* No. 125–1 (6).

In other States, including Kansas, Kentucky, Virginia, Tennessee, North Carolina, Louisiana, and Alabama, insufficient rootstock work with grapes has been done for any conclusions to be made, although there have been many valuable observations.

DISCUSSION

It is to be noted that in the Coastal States from South Carolina to Texas, wherever grape rootstock work is being done, the primary purpose is to increase the longevity of the vines. When this is accomplished the vigor and productivity are increased; also certain varieties then mature their fruit more evenly. In these States Dog Ridge, Champanel, and Lukfata have been outstanding. All of these have *Vitis champini* parentage; yet in Florida, where Lukfata is outstanding as a rootstock and the Champanel is very long-lived, the wild *V. champini* tried has not given good results. The first two years the scions on it have been vigorous, but a decline sets in and a good many vines are completely lost by the fourth year. No information was obtained about the Dog Ridge stock in Florida, and it may not yet have been thoroughly tested. It is possible, even though it is a pure *V. champini* selection, that it would respond differently from the particular wild *V. champini* that has been introduced and tested. However, it also is possible that none of the stocks adapted elsewhere in the country will prove entirely satisfactory for Florida conditions, and stocks may have to be developed specifically for that section, since most of the rootstocks used in the United States were developed and selected for conditions in California, France, or to some extent the northern grape districts of this country. In many of the Coastal States small vineyards may be found grafted on grapes brought in from the wild. Almost without exception these vineyards are thriving. Herein may lie the solution of the rootstock problem for these areas, if through hybridization the hardiness of these indigenous stocks may be combined with such desired qualities as ease of propagation, ease of budding and grafting, freedom from suckering, and so forth.

In the inland States in general, less grape rootstock work is being done than in the Coastal States, and the interest is in those stocks that will increase the vigor and yields rather than longevity. It is quite apparent that the loss of own-rooted vineyard vines is not great enough to be of serious concern.

Many State workers have felt that adaptation of "bunch" grapes in the South, or lack of it, is associated with elevation. This is especially true in South Carolina and Tennessee, where the elevations vary greatly and the production of own-rooted grape vines has been more successful at the higher elevations. No doubt there are other factors that are affected by elevation, such as length of growing season, rainfall, and temperature, which are all closely associated in the problem.

SUMMARY

This survey of the research work on rootstocks for "bunch" grapes in the South has shown that in the Coastal States from Texas to South Carolina the Dog Ridge, Champanel, and Lukfata stocks have been most effective in increasing the length of vine life and the yields of fruit. These stocks are all of *Vitis champini* parentage.

In the inland States the main emphasis is on rootstocks that will increase the yields, vigor, and evenness of ripening, especially of the weaker-growing varieties. The best stocks were found to be Constantia, riparia x rupestris 3309, cordifolia x riparia No. 125–1, Cynthiana, Wine King, and Lenoir. At the higher elevations these rootstocks were of less benefit than at the lower elevations.

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Influence of Indolebutyric Acid on the Rooting of Grape Cuttings

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DURING 1941 and 1942 experiments were conducted to test the effect of indolebutyric acid on the rooting behavior of cuttings of a few representative grape varieties. Species and varieties of Vitis used as rootstocks for grafted vinifera vineyards show a considerable variation in the degree with which they are able to develop roots from hardwood cuttings. While most cuttings of *Vitis vinifera* Linn., and of some American species root readily, those of other American species root very poorly.

The grape cuttings were treated with indolebutyric acid, in solution and as a powder. For the solution, 1 gram of acid was dissolved in 100 cubic centimeters of 95 per cent ethyl alcohol and then diluted with distilled water so as to give .001 per cent, .005 per cent, .01 per cent, .015 per cent and .02 per cent concentrations. Cuttings treated with distilled water served as checks. The cuttings were held upright in the liquids so that 1 inch of the basal ends was covered. During 1941, cuttings were treated for 8 hours, 16 hours and 24 hours. Since the 24-hour treatment gave a little the best results, only 24-hour treatments were given during 1942.

For the powder treatments, acid-talc concentrations of 1/1000, 2/1000 and 3/1000 were used. One gram of acid was dissolved in 100 cubic centimeters of ethyl alcohol. Of this acid solution, 10, 20 and 30 cubic centimeters were mixed with 100 grams of talc to make 1/1000, 2/1000 and 3/1000 concentrations respectively. In each case enough additional alcohol was added to make a soft paste which was dried to the powder state in the dark with the aid of a fan. The basal end of the grape cutting was wet with water, plunged ½ to 1 inch deep into the acid-talc mixture, jarred to remove loose particles and planted.

The grape cuttings used consisted of convenient lengths of 1-year-old dormant canes, usually with the basal ends cut just below a node; however where the word "internode" follows the variety name, the basal end was cut to the center of the internode.

Procedure and Results of 1941 Tests

Greenhouse Tests:—Three grape varieties were used: (Solonis x Othello) No. 1613 (hereafter referred to as the 1613 hybrid), a rootstock commonly used in the grafted vinifera vineyards of California and one that roots fairly well; Dog Ridge (*Vitis champini* Planch.), a vigorous rootstock which does not root quite as well as the 1613 hybrid; James (*V. rotundifolia* Michx.), considered a nonrooter from ordinary cuttings. Meyer lemon cuttings were grown for comparison. After receiving the varied treatments, the cuttings were planted January 10, 1941, in lots of 10 in a soil medium consisting of four parts by volume of sand and one of peat. At the end of 40 days, all were taken out and rated. The percentage of cuttings which had rooted was obtained, and the rooted cuttings were then rated for quality of root systems with 1 denoting rudimentary roots and 10 denoting excellent roots.

Untreated cuttings of the 1613 hybrid equaled the treated cuttings both as to number of cuttings rooting and quality of root systems (Fig. 1, A).

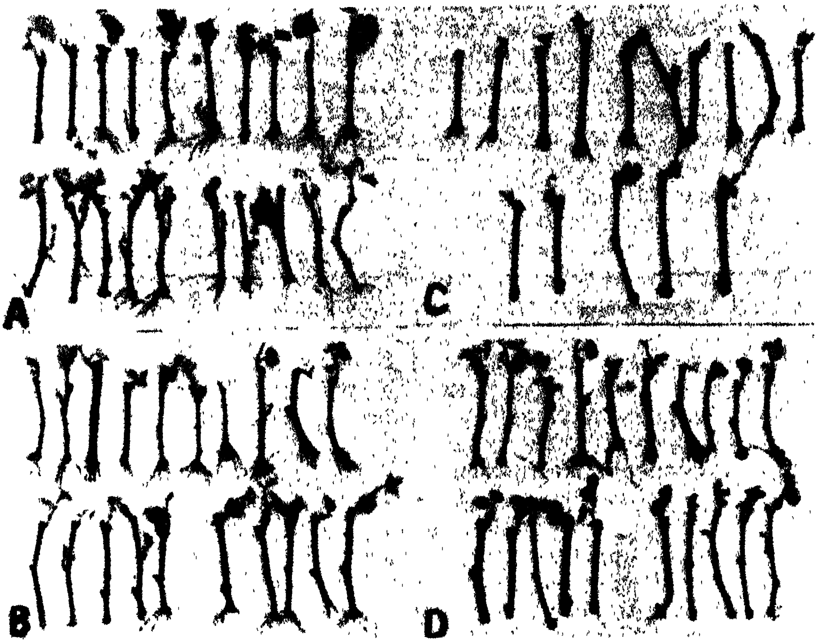

FIG. 1. Root formation at end of 40-day period on grape cuttings given various indolebutyric acid treatments, 1941.

A. Upper: 1613 hybrid, treated .005 per cent solution, 24 hours.
Lower: 1613 hybrid, untreated.
B. Upper: Dog Ridge, treated .015 per cent solution, 24 hours.
Lower: Dog Ridge internode, treated .015 per cent solution, 24 hours.
C. Upper: Dog Ridge, treated 3/1000 powder.
Lower: Dog Ridge, untreated.
D. Upper: Dog Ridge, treated .015 per cent solution, 24 hours.
Lower: Dog Ridge, untreated.

Dog Ridge cuttings, both regular and internode, were benefited by all treatments with indolebutyric acid in solution except the .001 per cent. The increase in rootings ranged from 6 to 34 per cent and the quality of the root systems was much better (Fig. 1, B and D). Dog Ridge treated with 3/1000 powder rooted better than the checks (Fig. 1, C).

Vitis rotundifolia failed to root with any treatment. The Meyer lemon treated with indolebutyric acid gave an increased percentage of rooting and the quality of the root systems improved with the strength of the solution.

Nursery Tests:—The following 25 varieties were treated with acid-talc 2/1000: Adobe Giant, Aramon x Rupestris Ganzin No. 2, Australis, Barnes, *Vitis berlandieri x riparia* No. 420-A, Chasselas x *V. berlandieri* No. 41-B, Constantia, *V. cordifolia x riparia* No. 125-1, Dog Ridge, *V. monticola x riparia* No. 18815, *V. monticola x rupestris,* Mourvedre x *V. rupestris* No. 1202, Ponroy, Riparia Gloire, *V. riparia x berlandieri* No. 161-49, *V. riparia x rupestris* No. 3309, Rupestris Pillans, Rupestris St. George, *V. rupestris x berlandieri* No. 301-A, *V. rupestris x cinerea, V. rupestris x cordifolia* No. 107-11, Salt Creek, Solonis x Othello No. 1613, Teleki 5-A, and Tisserand. Twenty-five untreated cuttings were planted 3 inches apart and in the same row following a 12-inch interspace were 25 treated cuttings.

Sixteen of these stocks gave a higher rooting percentage when treated, eight gave a higher rooting percentage when untreated and for one stock the rooting percentages were the same. For 15 stocks the quality of the root systems were better when treated and for 10 they were poorer.

The more striking differences found were as follows: Constantia, Dog Ridge, *Vitis monticola x rupestris,* Rupestris St. George, and Tisserand developed roots on from 24 to 36 per cent more cuttings when treated and in all cases except Tisserand developed distinctly better root systems. *V. berlandieri x riparia* No. 420-A and Riparia Gloire developed roots on 16 and 40 per cent more cuttings respectively and also better root systems, when untreated.

An additional 2/1000 acid-talc test was run with 2400 of the 1613 hybrid cuttings (three rows of 400 each being treated). When the cuttings were treated 1.7 per cent more of them rooted than when untreated. The quality of the root systems were almost the same for both lots.

Four grape varieties (Barnes, Dog Ridge, 1613 hybrid and Rupestris St. George) were treated with indolebutyric acid in solution. The water and five acid concentrations, and three time treatment periods listed in the beginning were used with 20 cuttings for each treatment.

No distinct trend was noted for any solution strength or period of treatment so only a general summary is given. When treated with indolebutyric acid solution, Barnes produced from 0 to 35 per cent (average 9.7 per cent) more rootings and better quality of root systems. With treatment, Dog Ridge gave 6.4 per cent average increase of rooting and a little better quality of root systems. There was little difference between solution-treated and the untreated cuttings of the 1613 hybrid. Judging from the top growth, there was little difference between solution-treated and untreated cuttings of Rupestris St. George. (The nursery digger destroyed so many rootings that a root check could not be obtained).

Procedure and Results of 1942 Tests

Greenhouse Tests:—Cuttings of *Vitis davidi* Foex, were treated in addition to the three used during 1941 (Dog Ridge, 1613 hybrid and *V. rotundifolia*). Cuttings of Meyer lemon were again treated for comparison. However, the majority of the tests concerned Dog Ridge and the 1613 hybrid cuttings.

Twenty cuttings for each treatment were planted January 1, 1942. In order to get a careful early and late check on the rooting conditions, 10 cuttings were taken out at 29 days and rated and the other 10 at 58 days. The treatments, rooting percentages and mean ratings for quality of root systems of the rooted cuttings for Dog Ridge and 1613 hybrid varieties are given in Table I.

Treating the 1613 hybrid with indolebutyric acid in liquid and powder state appeared to have a slight retarding effect on root development at 29 days, whereas, at 58 days there appeared to be a slight

TABLE I—EFFECTS OF INDOLEBUTYRIC ACID TREATMENTS ON ROOT FORMATION BY GRAPE CUTTINGS (1942)

Treatment*	After 29 Days			After 58 Days		
	Rooting (Per Cent)	Mean Ratings for Quality of Root Systems	Difference From Check‡	Rooting (Per Cent)	Mean Ratings for Quality of Root Systems	Difference From Check‡
1613 Hybrid						
Untreated	90	4.1 ±0.28	———	80	6.8 ±0.31	———
0.001	90	3.2 ±0.42	−1.80	70	5.6 ±0.66	−1.64
0.005	90	4.1 ±0.53	0.00	90	7.7 ±0.42	+1.73
0.01	50	3.2 ±0.13	−3.00	100	7.4 ±0.61	+0.88
0.015	80	3.4 ±0.18	−2.12	90	9.1 ±0.30	+5.47
0.02	50	3.2 ±0.54	−1.47	100	7.4 ±0.46	+1.09
Dog Ridge						
Untreated	60	2.5 ±0.41	———	80	4.1 ±0.29	———
0.001	70	2.7 ±0.24	+0.42	100	3.6 ±0.32	−1.19
0.005	80	3.9 ±0.53	+2.09	80	5.0 ±0.36	+0.87
0.01	90	2.6 ±0.32	+0.02	90	5.9 ±0.33	+4.18
0.015	100	3.6 ±0.39	+1.96	80	5.8 ±0.40	+3.47
0.02	80	2.9 ±0.39	+0.71	100	6.8 ±0.55	+4.35
1613 Hybrid						
Untreated	70	3.3 ±0.48	———	100	5.4 ±0.48	———
1/1000 powder	40	1.8 ±0.16	−2.94	90	7.8 ±0.40	+3.97
2/1000 powder	80	2.5 ±0.22	−1.31	80	6.6 ±0.51	+1.71
3/1000 powder	40	2.0 ±0.28	−2.36	50	5.8 ±0.92	+0.39
Dog Ridge						
Untreated	30	2.3 ±0.45	———	80	5.0 ±0.22	———
1/1000 powder	70	1 6 ±0.64	−0.90	60	5.5 ±0.59	+0.81
2/1000 powder	30	3.3 ±0.22	+2.00	60	5.7 ±0.45	+1.40
3/1000 powder	90	2.3 ±0.34	0.00	50	5.8 ±0.99	+0.79
1613 Hybrid						
Untreated	90	3.7 ±0.42	———	100	5.8 ±0.47	———
0.015	70	2.9 ±0.36	−1.45	100	5.6 ±0.64	−0.25
Untreated†	70	2.9 ±0.34	−1.48	100	4.7 ±0.38	−1.83
0.015†	100	4.0 ±0.42	+0.51	90	5.5 ±0.45	−0.46
Dog Ridge						
Untreated	70	3.3 ±0.12	———	90	4.2 ±0.49	———
0.015	90	4.0 ±0.32	+2.00	90	5.9 ±0.55	+2.33
Untreated†	20	2.0 ±0.67	−1.91	70	2.3 ±0.35	−3.16
0.015†	60	2.3 ±0.15	−5.00	50	4.2 ±0.54	0.00

*Numerals indicate percentage solution unless indicated otherwise.

†Basal cut made at center of the internode.

‡Difference from the check in terms of probable error. The probable error of the difference between two results is the square root of the sum of the squares of the probable errors of the two results. Differences are not to be considered very significant unless they are at least three times the probable error which means that the odds against such differences occurring under uniform conditions are 22 to 1.

improvement in the quality of the root systems following acid treatment, both powder and acid solution (Table I). The untreated regular cuttings of the 1613 hybrid rooted a little better than did the untreated internode cuttings. The acid was of slight benefit to the internode cuttings of 1613 but not to the regular cuttings (Table I). The percentages of cuttings rooting for checks and treatments were so variable that differences do not seem significant.

The quality of the roots of the Dog Ridge cuttings was improved by all concentrations of the indolebutyric acid solution treatments except the .001 per cent, (Table I). The improvement was more marked for the 58-day period than the 29-day period. The improvement in root quality from the acid in talc was slight. The quality of roots was better for the Dog Ridge regular cuttings than for the Dog Ridge internode cuttings; however, the .015 per cent acid treatment improved the quality of the roots of each type of cutting a little. The percentage of cuttings rooting varied a great deal for both treated and untreated cuttings so that no significant differences were established.

The quality of the Meyer lemon roots was improved by all treatments except the .001 per cent indolebutyric acid. The development of the treated lots in comparison with the check was about the same at 29 and 58 days.

Vitis rotundifolia failed to root either with or without treatments. Only 10 per cent of the *V. davidi* cuttings treated with .005 per cent, .01 per cent and .015 per cent solutions rooted. Since 10 per cent of the untreated cuttings rooted, no benefit was derived from the acid treatment on *V. davidi* cuttings.

Nursery Tests:—The 25 stocks grown during 1941 in lots of 50 cuttings were grown again in lots of 50 cuttings with the exception of Rupestris Pillans and 1613 hybrid. Also six new stocks were added to the group (*Vitis arizonica* Engelm., *V. berlandieri* Planch., No. 1, *V. candicans* Engelm., James (*V. rotundifolia*), Lenoir and *V. riparia x rupestris* No. 101–14). The treated cuttings of the various varieties were planted in one row and the untreated cuttings in an adjacent row to avoid any possible acid movement in the irrigation water from treated to untreated cuttings. The percentage counts of cuttings growing in the nursery were made before the nursery plants were dug. No ratings were made for quality of root systems. It was the intention to use only acid-talc concentration 3/1000 during 1942 nursery trials but a miscalculation was made in the quantity needed so 10 varieties were treated with 3/1000, 13 with 2/1000, and 6 with 1/1000 concentrations. However, a careful check was made at the end of the season and no pronounced effects were evident as a result of this variation in treatment.

Thirteen of these stock varieties gave a higher rooting percentage when treated, ten gave a higher rooting percentage when untreated and for six the rooting percentages were the same.

The more striking differences found were as follows: Aramon x Rupestris Ganzin No. 2, *Vitis monticola x riparia* No. 18815, *V. riparia x berlandieri* No. 161-49, Rupestris St. George, *V. rupestris x cordifolia* No. 107-11, and Salt Creek developed roots on from 16 to 36 per cent more cuttings when treated. *V. berlandieri x riparia* No. 420-A, *V. cordifolia x riparia* No. 125-1, and *V. monticola x rupestris* developed roots on 16 per cent less cuttings when treated.

Rupestris St. George was the only stock grown in the nursery to which acid-talc treatments brought distinct improvement in quality of root systems during 1941 and in percentage of cuttings rooting during both 1941 and 1942. In contrast to this, *Vitis berlandieri* x *riparia* No. 420-A developed roots on 16 per cent less cuttings during both 1941 and 1942 when treated with the acid-talc mixture. During 1941 *V. monticola* x *rupestris* showed a 28 per cent rooting improvement and a very distinct root quality improvement with the acid-talc treatment but in 1942 with treatment it rooted 16 per cent less cuttings.

An additional acid-talc test 3/1000 was run with 2000 of the 1613 hybrid cuttings (two rows of 400 cuttings each being treated). The treated cuttings rooted 12.4 per cent better than the untreated cuttings but the per cent of treated cuttings that rooted was only 34.9.

Only two varieties (Barnes and Dog Ridge) were treated with indolebutyric acid solution and planted in the nursery during 1942. For some unaccountable reason, this planting was almost a failure but the 80 untreated cuttings rooted as poorly as the 300 treated cuttings so the failure was not due to the acid treatment.

CONCLUSIONS

The results of treating grape cuttings with indolebutyric acid varied considerably with different varieties. Dog Ridge and Barnes were distinctly benefited especially in the production of better root systems. The effects on No. 1613 hybrid (Solonis x Othello) were negative or of very doubtful value. Indolebutyric acid did not stimulate rooting of cuttings of *Vitis rotundifolia* or of *V. davidi*. Meyer lemon cuttings were distinctly benefited by acid treatment. In the case of varieties that were benefited, concentrations of .005 per cent to .02 per cent for 24 hours gave somewhat uniformly beneficial results.

When the basal end of the cutting included part of an internode, roots formed mainly at the bottom of the internodal section; but it appears that a cutting with a node at the base furnishes a little better condition for root development.

In the nursery, 31 rootstock varieties were grown after being treated with acid-talc mixture. Some showed benefits, some were variable, and some were unaffected. The tests so far conducted have not shown distinct commercial benefits from the acid-talc nursery treatments.

A Comparison of Bench-Grafted and Field-Grafted Vinifera Grape Vines

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IN THE spring of 1937, an experimental planting was made at Fresno, California, to compare bench-grafted with field-grafted grape vines. Many vinifera and American native grape varieties, both bench-grafted and field-grafted, have grown satisfactorily in the Federal Experiment Vineyards for 30 years or more. These older plantings were not made, however, to compare the two grafting procedures. Since it is quite well established that grafted vines produced by either procedure are satisfactory, the main objective of the present test was to compare the growth and fruit production during the first several years after grafting. These grafting procedures differ mainly in the way in which the final grafted plants are obtained. Bench-grafted vines, usually supplied by commercial nurseries, result from grafting the desired vinifera scions on rootstock vine cuttings and growing the resulting plants one year in nursery rows previous to field planting. When field-grafting is practiced, 1-year-old rootstock vines are planted in the vineyard in the spring and field-grafted the same fall or the following spring with the desired vinifera varieties.

The planting consisted of 10 plants of each of 10 varieties, a total of 100 vines bench-grafted on Rupestris St. George rootstock and the same number of these varieties field-grafted on rooted vines of Rupestris St. George. The planting was in four alternating rows of 50 vines in each row. Both bench-grafted plants and rootstock vines were selected for uniformity. The rootstock vines were field-grafted by the bud-graft method (1) in the fall of 1937. Thus in the spring of 1938, five bench-grafted vines alternated across the four rows with five field-grafted vines of each of the 10 vinifera varieties, making a total of 10 vines of each variety bench-grafted and 10 vines field-grafted. Stands of 99 per cent of bench grafts and 92 per cent of field-grafts were obtained. All vines received practically the same pruning and cultural treatment. The soil was not entirely uniform and less growth was produced than might be expected, but with the bench grafts alternating across the plot with the field grafts, the effects of the poorer soil spots on the results of the experiment were reduced.

The comparative data obtained included trunk measurements, weight of brush removed at pruning time, and fruit yields. Data on the increase of trunk size were obtained by measurements taken at the time of planting and at the end of the 1942 growing season, a lapsed period of 5 years. Pruning brush weights were obtained from each vine from 1939 to 1941 inclusive. Fruit records were obtained during the 1940 and the 1942 seasons, and the average annual yields for the two years were obtained. A condensed summary of these data is given in Table I.

Table I shows that the bench-grafted and field-grafted vines were about equal over the 5 year period, and observations over the period did not indicate any radical difference between the vines established by the two grafting procedures. The growth of vines as measured by

TABLE I—COMPARATIVE GROWTH AND FRUIT YIELD OF YOUNG BENCH-GRAFTED AND FIELD-GRAFTED VINES

Varieties Grafted on Rupestris St. George Rootstock	Trunk Circumference Increase (Cms) Average Per Vine (1937 to 1942)		Weight of Prunings (Lbs) Average Per Vine (1939 to 1941)		Weight of Fruit (Lbs) Average Per Vine (1940 to 1942)	
	Bench-Grafted	Field-Grafted	Bench-Grafted	Field-Grafted	Bench-Grafted	Field-Grafted
Cabernet Sauvignon. . . .	9.29	9.72	2.93	3.90	1.67	2.17
Gamay Burgundy.	4.47	5.92	1.86	2.28	8.43	8.50
Green Hungarian.	5.59	5.02	2.83	1.90	8.69	6.84
Insolia bianca.	8.37	6.59	2.14	1.74	3.13	3.45
Malaga.	9.09	7.79	3.69	3.37	7.69	4.68
Mataro.	5.36	5.12	2.29	1.66	6.14	4.46
Muscat Frontignan . . .	3.75	5.52	1.93	2.14	2.62	2.08
Muscat Hamburg.	5.90	5.49	2.99	3.70	6.44	5.32
Olivette blanche	10.67	12.39	4.07	5.35	8.94	7.71
Rose of Peru.	10.59	10.27	3.75	4.13	5.98	4.49
Average of all varieties. .	7.31	7.39	2.85	3.02	5.97	5.01

the trunk circumference increase was quite similar. While the varieties varied among themselves in amount of trunk growth, the growth increase in trunk size was relatively uniform for the same variety. In the case of two varieties, Insolia bianca and Malaga, the trunk increase in size was decidedly greater for the bench-grafted vines. With two other varieties, Muscat Frontignan and Olivette blanche, the field-grafted vines made the larger trunks. The average per vine increase for all varieties, bench-grafted and field-grafted, is as nearly identical as could be expected under field conditions.

The weight of prunings in Table I represent the average amount of brush per vine removed annually over the 3 year period. Four varieties bench-grafted produced more brush than the same varieties field-grafted. Six of the varieties produced more brush when field-grafted than when bench-grafted. In the average of all 10 varieties, the field-grafted vines slightly exceeded the bench-grafted vines in weight of prunings. This slight increase in brush does not appear significant.

The weight of fruit given in Table I represents the annual average per vine for the two years, 1940 and 1942. The yields in 1940, the first year of bearing, were less than in 1942 but the trends were very similar for both bench-grafted and field-grafted vines. Hence in the condensed table, the yields per vine. for the two years were combined and averaged to represent the average annual yield per variety. There was no decided advantage in fruit yield for either the bench-grafted or field-grafted lots. In the average of all varieties, the fruit production of the bench-grafted vines slightly exceeded the field-grafted plants.

During the first 5 years in vineyard form, the growth and fruit production of both bench-grafted and field-grafted vinifera vines were very similar. Under comparable conditions there was no decided trend in favor of either grafting procedure in establishing vinifera varieties on resistant rootstocks.

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Further Studies on the Adaptability of Some American Grape Varieties to Southern Conditions When Grown on Their Own Roots and on Certain Stocks

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A 6-YEAR test of 10 grape varieties grown on their own roots and on 10 rootstocks was made at the United States Horticultural Field Station, Meridian, Mississippi, and reported in 1939 (4). The experiment was continued two more years and significant changes occurred which are reported herein. No attempt will be made at this time to supplement that portion of the earlier report regarding own-rooted grape varieties. The rootstocks tested were: Aramon x Rupestris Ganzin, No. 2, *Vitis berlandieri* x *V. riparia,* No. 420-A; Constantia; Dog Ridge; *V. monticola* x *V. riparia,* No. 18815; Mourvedre x *V. rupestris,* No. 1202; *V. riparia* x *V. rupestris,* No. 101–14; *V. rupestris* x *V. cordifolia,* No. 107–11; Rupestris St. George, and Solonis x Othello, No. 1613. Each full stock-scion test consisted of six vines. However, in all cases a full stand of plants was not obtained. Where this occurred, the stock vine filled the position in the vineyard so that the surrounding vines were not favored by a vacancy. The plan and treatment of the experiment were given in the original paper and the details may be found there; subsequent treatment was the same or similar and uniform throughout the entire test block.

Only the summarized data based on the living vines for the growing season of 1941 are presented because these figures tend to emphasize the differences more than the averaged data for the duration of the experiment. The yield records are based upon those vines which were living at the time of harvest in July and August of 1941. The survival and weight of pruning data are based upon those vines surviving in January 1942. Vine mortality after harvest accounts for those cases where the percentage of survival is zero yet a yield is recorded. The data are presented in Table I.

By ranking the stocks in four groups according to relative longevity, the outstanding ones in order are Dog Ridge; *Vitis berlandieri* x *V. riparia,* No. 420-A; Rupestris St. George; and Solonis x Othello, No. 1613. These four stocks classified in a similar way on the basis of yields and vigor as measured by pruning weights rank: Best, Dog Ridge; medium, *V. berlandieri* x *V. riparia,* No. 420-A; and fair, Rupestris St. George and Solonis x Othello, No. 1613. Although no one stock was best for all the 10 scion varieties tested, the Dog Ridge stock gave best results most frequently, and by all criteria was highly superior to the other rootstocks.

The scion varieties Herbemont and Lenoir were influenced less by the rootstocks than the other scions and gave satisfactory results on their own roots. The varieties Catawba, Ellen Scott, Goethe, and

TABLE I—SHOWING PERCENTAGE SURVIVAL, PRODUCTIVITY, AND VIGOR OF THE SURVIVING VINES OF 10 AMERICAN GRAPE VARIETIES AT THE END OF THE EIGHTH SEASON, WHEN GROWN ON VARIOUS ROOTSTOCKS AND ON THEIR OWN ROOTS AT MERIDIAN, MISSISSIPPI (YIELDS OF FRUIT AND PRUNINGS ARE EXPRESSED AS POUNDS PER VINE)*

	Scion Varieties									
	Concord	Delaware	Carman	Lenoir	Herbemont	Catawba	Manito	Ellen Scott	Goethe	Extra
Aramon × Rupestris Ganzin, No. 2										
Per cent survival Jan 1942	67.0	0.0	80.0	100.0	0.0	60.0	0.0	0.0	0.0	25.0
Average fruit 1941 (lbs)	10.3	0.0	36.7	44.5	0.0	15.5	5.5	8.8	0.0	0.6
Average prunings 1942 (lbs)	7.1	0.0	8.5	8.2	0.0	5.1	0.0	0.0	0.0	2.2
V. berlandieri × V riparia, No. 420-A										
Per cent survival Jan 1942	67.0	40.0	100.0	100.0	50.0	20.0	0.0	25.0	0.0	100.0
Average fruit 1941 (lbs)	5.7	13.8	21.2	33.7	4.5	25.5	0.0	16.3	1.7	11.5
Average prunings 1942 (lbs)	0.7	2.2	5.1	5.8	9.2	3.0	0.0	7.4	0.0	5.1
Own Roots										
Per cent survival Jan 1942	0.0	50.0	67.0	100.0	100.0	0.0	0.0	0.0	0.0	83.0
Average fruit 1941 (lbs)	0.0	12.8	19.1	33.1	19.9	10.5	0.0	0.0	0.0	8.3
Average prunings 1942 (lbs)	0.0	2.8	6.3	7.0	11.5	0.0	0.0	0.0	0.0	11.1
Constantia										
Per cent survival Jan 1942	17.0	0.0	0.0	67.0	100.0	25.0	0.0	0.0	0.0	33.0
Average fruit 1941 (lbs)	8.8	0.0	0.0	21.9	11.0	5.2	3.5	4.0	0.0	2.5
Average prunings 1942 (lbs)	2.3	0.0	0.0	5.5	5.6	0.9	0.0	0.0	0.0	0.4
Dog Ridge										
Per cent survival Jan 1942	83.0	100.0	25.0	67.0	67.0	40.0	0.0	0.0	50.0	100.0
Average fruit 1941 (lbs)	17.7	25.5	33.5	23.9	20.9	19.1	23.4	0.0	10.8	19.3
Average prunings 1942 (lbs)	7.7	5.6	11.1	6.3	6.6	6.6	0.0	0.0	14.3	14.4
V. monticola × V. riparia, No. 18815										
Per cent survival Jan 1942	0.0	0.0	25.0	100.0	80.0	0.0	0.0	0.0	0.0	0.0
Average fruit 1941 (lbs)	0.0	0.0	16.4	23.0	16.8	0.0	0.0	0.0	0.0	0.0
Average prunings 1942 (lbs)	0.0	0.0	6.0	3.7	4.9	0.0	0.0	0.0	0.0	0.0
Own Roots										
Per cent survival Jan 1942	0.0	83.0	67.0	100.0	100.0	0.0	0.0	0.0	0.0	83.0
Average fruit 1941 (lbs)	0.0	16.3	13.7	26.4	19.1	20.1	0.0	0.0	0.0	11.5
Average prunings 1942 (lbs)	0.0	3.0	5.7	6.9	13.3	0.0	0.0	0.0	0.0	9.8
Mourvedre × V. rupestris, No. 1202										
Per cent survival Jan 1942	0.0	0.0	0.0	67.0	—†	0.0	0.0	0.0	0.0	25.0
Average fruit 1941 (lbs)	0.0	0.0	8.2	19.0	—	0.0	0.0	0.0	0.0	28.7
Average prunings 1942 (lbs)	0.0	0.0	0.0	6.5	—	0.0	0.0	0.0	0.0	16.6
V. riparia × V. rupestris, No. 101-14										
Per cent survival Jan 1942	17.0	100.0	0.0	100.0	0.0	40.0	0.0	0.0	0.0	33.0
Average fruit 1941 (lbs)	0.1	8.9	0.0	18.6	0.0	7.3	0.0	0.0	0.0	7.1
Average prunings 1942 (lbs)	0.7	2.0	0.0	3.5	0.0	5.1	0.0	0.0	0.0	6.6
V. rupestris × V. cordifolia, No. 107-11										
Per cent survival Jan 1942	0.0	0.0	0.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0
Average fruit 1941 (lbs)	0.0	0.0	0.0	20.5	0.0	0.0	0.0	0.0	0.0	0.0
Average prunings 1942 (lbs)	0.0	0.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0
Own Roots										
Per cent survival Jan 1942	0.0	33.0	67.0	100.0	100.0	0.0	0.0	0.0	0.0	83.0
Average fruit 1941 (lbs)	0.0	10.3	9.8	24.8	23.0	0.0	0.0	0.0	0.0	11.8
Average prunings 1942 (lbs)	0.0	3.9	3.4	6.6	8.9	0.0	0.0	0.0	0.0	11.6
Rupestris St. George										
Per cent survival Jan 1942	0.0	100.0	100.0	80.0	—	17.0	0.0	25.0	25.0	0.0
Average fruit 1941 (lbs)	2.0	20.2	12.6	7.1	—	1.0	1.2	9.3	2.2	0.0
Average prunings 1942 (lbs)	0.0	5.7	3.5	2.2	—	3.7	0.0	4.0	8.6	0.0
Solonis × Othello, No. 1613										
Per cent survival Jan 1942	0.0	67.0	100.0	100.0	75.0	0.0	0.0	0.0	0.0	60.0
Average fruit 1941 (lbs)	0.6	17.3	12.2	25.9	20.2	0.0	0.0	6.4	0.0	4.3
Average prunings 1942 (lbs)	0.0	3.2	3.3	6.8	14.3	0.0	0.0	0.0	0.0	3.5

*Percentage of survival and pruning weights are based on records of January 1942, and yields on records of July and August 1941.

†No scions established on this rootstock.

Manito were favorably influenced by certain of the stocks, but their life was short regardless of the rootstock used. However, it is evident from the report of 1939 (4) that the life of these four scion varieties was increased by the four stocks which were outstanding for all the scions as a group during the season of 1941. The Concord and Delaware scions were more influenced by certain compatible stocks both in yields and quality than any of the other scion varieties.

Concord in the South has a tendency to ripen its fruit unevenly so that there are ripe berries and green berries in the same cluster. Recent work (1, 2, 3, 6) has shown that increasing the leaf area/fruit ratio of Concord grapes will decrease the amount of uneven ripening. All stocks which increased the vigor of Concord scions increased the percentage of marketable fruit. Delaware on its own roots and on vines which bore heavily in relation to their vigor, produced fruit which failed to color or colored late. This fruit was of extremely poor quality and low sugar content. Here again the rootstocks which increased the vigor increased the amount of marketable fruit.

The superiority of Dog Ridge over the other stocks was greater than it was in 1939. The Aramon x Rupestris Ganzin, No. 2 stock which was rated as very good in 1939 declined sharply during the following two years. The performance of this stock was in marked contrast to its performance in the 5-year test of ungrafted stock vines conducted at Poplarville, Mississippi (5) where it failed completely. Studies by Snyder (7) have shown it to be highly susceptible to rootknot nematode which undoubtedly hastened its death at Poplarville, whereas in the Meridian test it was planted on heavy clay soil which was not favorable to the development of the rootknot nematode.

SUMMARY

Ten grape varieties were tested for 8 years at the United States Horticultural Field Station, Meridian, Mississippi, on their own roots and on 10 grape rootstocks. The yields and longevity of 8 of the 10 varieties were greatly increased by congenial stocks adapted to the environment. The Dog Ridge (*Vitis champini*) rootstock was superior to all other stocks tested on the basis of longevity, yields, and vigor of the scions as measured by the pruning weights. Fair to medium rootstocks were *V. berlandieri* x *V. riparia*, No. 420-A; Rupestris St. George; and Solonis x Othello, No. 1613; poor, Aramon x Rupestris Ganzin, No. 2; Constantia; *V. monticola* x *V. riparia*, No. 18815; Mourvedre x *V. rupestris*, No. 1202; and *V. rupestris* x *V. cordifolia*, No. 107–11.

The length of life of vines and yields of fruit of Concord and Delaware varieties were increased more by compatible stocks than were those of the others tested, the yields being comparable with those obtained in commercial grape-producing areas farther North. The amount of marketable fruit was likewise increased and the quality superior to that from own-rooted vines. The use of rootstocks, however, did not obviate the necessity of maintaining a high ratio of leaf area to fruit set in order to assure high quality.

The bourquiniana scion varieties Herbemont and Lenoir were little

if any benefitted by the stocks tested as compared with own-rooted vines.

The varieties Catawba, Ellen Scott, Goethe, and Manito were short-lived regardless of the rootstock used, but their life over that of own-rooted vines was materially increased by the better rootstocks.

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Selection for Fruit Color in the Emperor Grape

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THE Emperor is a late-maturing table grape, grown near the foothills in Tulare and Fresno counties on the eastern side of the San Joaquin Valley. It ranks third among the table-grape varieties of California. The acreage in 1941 was 21,491 (1). Its dark red color adds much to its attractiveness and markedly influences the price obtained by the grower.

Within recent years, growers have become increasingly concerned over the failure of many Emperors "to color." The problem is not new, however, as it was considered by both growers and the Tulare County Farm Advisor's Office as much as 15 years ago. The establishment of market grades for Emperor grapes has focused more attention on the difficulty. In some vineyards much of the fruit has developed only a pale pink color or remained almost wholly green and unsuited for interstate shipment. Such fruit must be marketed locally as "white Emperor," or be sold to alcohol distilleries. Vines producing poorly colored clusters are found mixed in with vines that produce crops of a high commercial quality. The differences in fruit color — even between adjacent vines — may range from excellent to almost no color. The failure to develop color has often been attributed to the use of a rootstock variety, the Solonis x Othello 1613, on which many of the younger vineyards have been established by field budding. Other suggestions have been advanced, such as a degeneration of the Emperor variety owing to an obscure disease or the origin of strains by somatic mutation.

The color development of four vineyards has been mapped for 2 years or more. A portion of one of these that has been longest under our observation will be used to show the variation in color development between vines. In 1938, 1939, 1941, and 1942, the color of the crop on each vine was given a rating of 1, 2, 3, or 4, the rating 1 indicating only a tinge of color on the well-exposed berries; 2 indicating approximately one-half normal coloring; 3 indicating the most desirable color for commercial shipment; and 4 indicating a dark reddish-black color. Although fruit of the latter rating is considered the most palatable of all, the color is too dark for the best commercial quality. The authors experienced but little difficulty in rating the color of the fruit of the different vines.

Examination of Fig. 1 indicates that each vine tends to produce fruit of about the same color year after year. Of 51 vines scored for four seasons (rows 6–11), 38 were rated in the fall of 1938 as 1 or 2, while in 1942, 36 of them were still rated 1 or 2, which represents 76 and 71 per cent respectively with poorly colored fruit. Only eight vine crops of the total 152 vine crops harvested in four seasons of record were of good market quality as far as color was concerned. Those vines rated as producing superior fruit continue to do so in the great majority of cases, even with certain seasonal fluctuations in

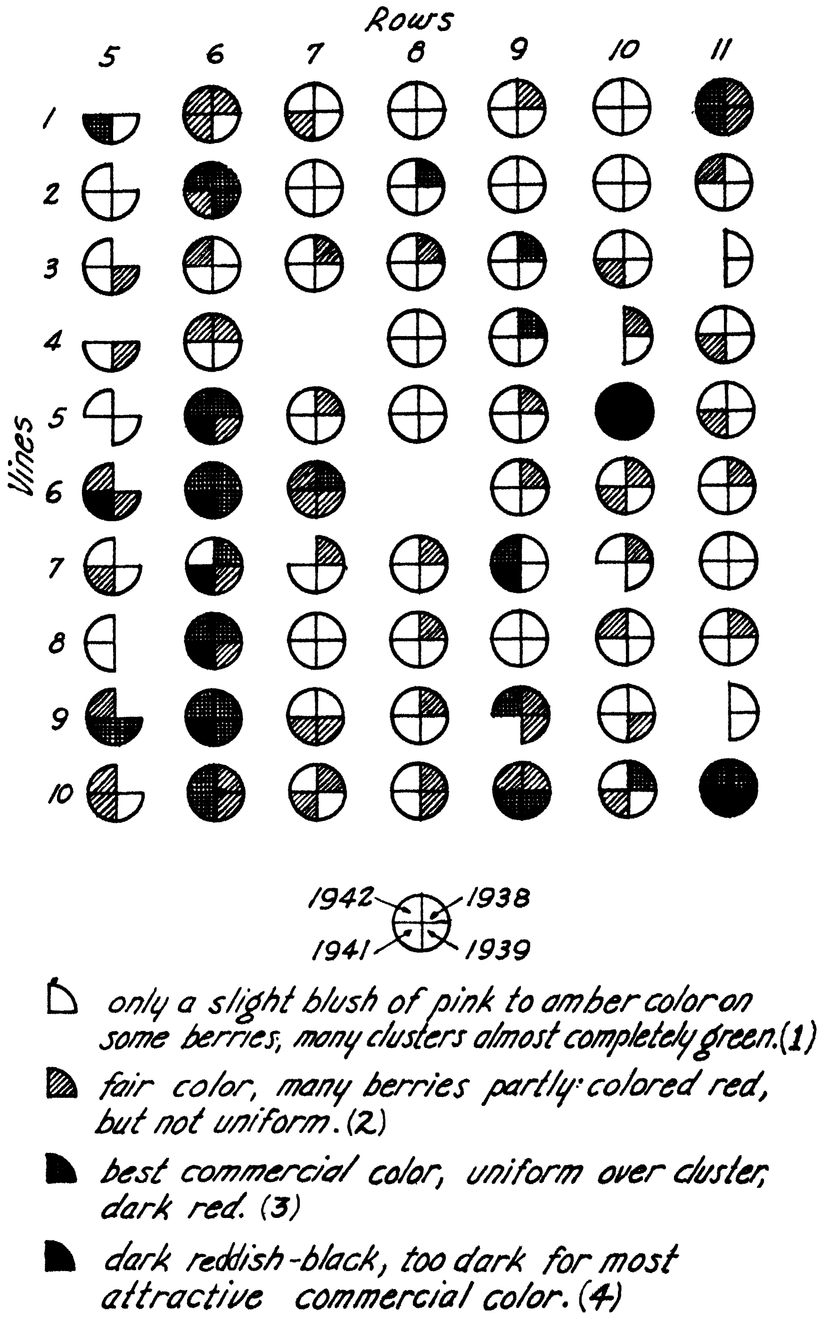
Rows
5
6
7
8
9
10
11
Vines
1
2
3
4
5
6
7
8
9
10
1942
1938
1941
1939
only a slight blush of pink to amber color on some berries; many clusters almost completely green. (1)
fair color, many berries partly colored red, but not uniform. (2)
best commercial color, uniform over cluster, dark red. (3)
dark reddish-black, too dark for most attractive commercial color. (4)

FIG. 1. Map of the List vineyard, showing field ratings for fruit color for 1938, 1939, 1941, and 1942.

climate and cultural practices that are unquestionably important in influencing fruit color. The general picture, therefore, is indicative enough—the wide range of color variation in this vineyard is mainly the result of individual vine variation. The major variation is inherent in the vine itself.

There are two exceptional vines in the plot that do not conform to the usual behavior. They are vine 7 in row 6 (6–7) and vine 7 in row 9 (9–7). In 1941 vine (6–7) rated 4, but in 1942 it produced poorly colored fruit with 1 rating. The other exceptional vine (9–7) produced poorly colored fruit in 1938 and 1939, but in 1941 and 1942 the fruit was of good color. The authors have no adequate explanation for these reversals at the present time. Longer performance records and progeny tests are necessary.

The distribution of vines regularly producing fruit of either poor or good color is not entirely at random in many of the young Emperor vineyards. Very often in the same row a number of successive vines have the same color rating. This is illustrated in the map of the vineyard herein presented. Thus in row 6, vines 5 to 10 inclusive would appear to have come originally from the same vine. This is not improbable, as in field budding a number of successive vines are usually grafted from the same bud stick (cutting). The successive appearance, therefore, of similar color types in the direction of the vines, in which direction the budding is done, and the more random appearance of color types across the rows adds evidence that the different types were propagated from pre-existent ones. Another type of evidence is available. If a vine dies out, it is usually replaced by layering a cane from an adjacent vine and establishing a new vine on its own roots, the cane connecting with the mother vine (on 1613 rootstock) being severed, usually after two years. Three cases have been observed in which such layers had been severed from the mother vine. In each instance, after growing on its own root system for two years, the vine produced fruit of exactly the same rating as the mother vine from which it originated. Observations of many such cases must of course be continued for a longer period of time, but the results would indicate that one can expect to generally obtain the same fruit color type as the parent vine, irrespective of whether the vine was growing on its own roots or was grafted on 1613 rootstock.

PROGENY TESTS

In the spring of 1938 cuttings were obtained from five selected vines in the mapped area of the vineyard. Each selection was numbered, the row number appearing first, followed by the vine number. The selected cuttings were grafted at Davis on two rootstocks, the 1202 and 3309, so that two vines were reproduced for each selection. During the 1941 and 1942 seasons, the total crop was harvested from each vine. They were then rated for color visually, as was done in field mapping. The whole sample, that is, the crop of each vine, was then crushed and a sample of the juice used for sugar determination with the Balling hydrometer. The acid was determined as grams of tartaric acid per 100 ml. of juice, using NaOH for the titration and phenolphthalein as indicator. In order to have a quantitative measure of the fruit color, a procedure was used similar to that reported by Williams (2), making use of an Evelyn type photoelectric colorimeter.

Inspection of the color data (Table I) shows strikingly that the selections have maintained their same relative value, reproducing the characteristic fruit color of the parent vines from which they were obtained, for the two years of sampling. Thus vine 10–5 has consistently produced very dark-colored fruit (rating 4) at Exeter. When propagated at Davis the same is true, it produces more highly colored fruit than any of the other selections. Parent vine 6–2 has produced the fruit with the best commercial color in three out of four seasons. The vines of this selection at Davis have likewise produced the best commercial color. The other three selections — 5–7, 5–10, and 6–4 — appear to behave similarly, and the data thus far indicate that they are of similar origin. If this be true, then all of the vines generally giving poorly colored fruit would be of the same type, the recorded seasonal differences in color of individual vines being explained by environmental factors — climatic, nutritional, and cultural factors all being of some importance.

TABLE I—INDIVIDUAL VINE SELECTIONS FROM THE LIST VINEYARD PROPAGATED AT DAVIS (CROPS OF 1941 AND 1942)

Selection Number	Root-stock	Yield (Kgs.)		Balling		Acid*		Color			
								Visual		Density x 100	
		1941	1942	1941	1942	1941	1942	1941	1942	1941	1942
(10-5)	1202	3.77	3.93	23.5	20.0	.59	.56	4	4	64	66
	3309	5.66	3.63	21.6	21.4	.67	.68	4—	4	46	41
(6-2)	1202	2.00	1.35	20.9	17.7	.52	.76	3	3	28	27
	3309	10.9	8.94	20.1	18.0	.66	.72	3	3	19	20
(5-7)	1202	0	2.90	—	14.4	—	.70	—	1	—	9
	3309	8.51	7.96	17.3	11.5	.72	.83	1	1	8	5
(5-10)	1202	4.46	9.24	16.6	14.4	.57	.53	1	1	6	9
	3309	5.84	5.61	15.9	11.0	.57	.62	1	1	7	5
(6-4)	1202	1.60	5.96	16.8	13.7	.61	.55	2—	1	7	7
	3309	3.62	7.31	18.3	13.1	.44	45	2	2—	15	12

*Grams per 100 cubic centimeters of juice, as tartaric.

The selections with poor fruit color invariably have lower sugar contents than those with good color. High sugar content is directly correlated with intensity of coloring. This readily explains why the poorly colored fruit has always been of such low market value, even aside from the deficient color. It is definitely of very poor palatability. The total acidity of the fruit, as expressed as tartaric acid, appears to show no relationship to fruit color in these selections. One might suspect that the poorly colored vines were those that were overcropped, but such is not the case. In Table II, it will be noted that the yields are actually less for all of the poorly colored selections, nor is there a consistent relationship between yield and fruit color in the data presented in Table I.

TABLE II—FRUIT OF THE LIST VINES FROM WHICH THE DAVIS VINES WERE PROPAGATED (1942)

Row and Vine	Rootstock	Yield (Kgs)	Balling	Acid	Visual	Density × 100	Remarks
(10-5)	1613	8.90	20.8	0.33	3+	31	Fruit of good commercial quality.
(6-2)	1613	8.10	19.9	0.32	3	24	Fruit of very good commercial quality.
(5-7)	1613	6.95	14.2	0.33	1	10	These samples appear similar in all respects. They have shorter berries than the above lots, taste sour, and the color is limited to a faint blush on most berries, many are entirely green or amber.
(5-10)	1613	4.80	16.1	0.32	2	14	
(6-4)	1613	3.11	17.4	0.30	2	15	

Certain morphological features are associated with vines regularly producing poorly colored fruit, that is those rated 1 or 2. The foliage becomes noticeably redder and more bronzed rather early in the fall. The fruit clusters are composed of berries of normal size, but in many seasons they appear more rounded in shape. In contrast, vines rated consistently as 4 produce somewhat smaller berries and clusters than the best commercial type.

DISCUSSION

The data presented show definitely that the present failure of the Emperor grape to color can be attributed largely to the existence of individual vines that inherently produce fruit of poor color under present commercial practices. This has been further demonstrated by progeny tests, since propagation of vines that produce fruit of a given color range gives rise to other vines that show the same characteristics. Propagation from vines that have consistently produced fruit of good commercial color can be expected to improve markedly the average color quality of the fruit in new vineyards. The present practice of planting or grafting new acreage with cuttings gathered at random should be discontinued.

Reference has been made to the fact that in a group of five vines selected for asexual progeny tests there were apparently only three well-defined types. The first is the undesirable type which fails to color properly and has been usually rated as 1 or 2. It is characterized by other morphological features as well as poor fruit color. The second type of vine is what we might consider to be the "normal" Emperor: it produces fruit that is of good commercial quality and has represented the variety as it was originally known. The third type is one of much darker color than the "normal." This form appears only infrequently in vineyard plantings.

Until further work is completed no definite conclusions can be had concerning the origin of these color variants. It would be well to enumerate the possibilities as a basis for further work. The idea of somatic variation is not dismissed. Crosses to determine if the changes are entirely genetic in nature have already been made. The possible existence of a virus disease that reproduces itself without noticeable reduction in the vigor or yield of the vine, yet produces changes like those described, must also be taken into consideration. Reciprocal grafts of the color variants are now being made to determine if such differences are transmissible.

However, the generally held opinion that the 1613 rootstock is largely responsible for failure of coloring receives no support, unless this is an indirect effect. For example, if some vines of the 1613 stock were themselves carrying a virus, then propagation of a "normal" colored or healthy strain would show the effects in the production of poorly colored fruit when grafted upon them. Even this explanation would not account for the existence of the third type, the dark-colored one.

Notwithstanding the difficulty in presenting an adequate explanation for the origin of these color types, it is apparent that growers should pay particular attention to the selection of the vines producing fruit of the most desirable color in their vineyards if production of poorly colored fruit is to be reduced. A practical method of selection would be to mark a large number of vines that have produced the best commercial color for at least two years, and preferably for three. These vines should be selected from vineyards adjacent or close to the area to be planted in new vineyard. In this way color variations owing to location are reduced to a minimum. The advantage of marking vines for fruit color for more than a single season is obvious. This would take care of any seasonal variation that might occur.

The significance of the present study in relation to experimental work with the Emperor grape should not be overlooked. Plots for experimental studies involving such procedures as fertilization, rootstock effects, etc., obviously should be chosen with care to make sure that a number of varietal types are not involved. Of course, the most desirable procedure would be the establishment of experimental plots by propagation from a single or a few selected vines. This should insure, as far as practicable, the use of a single clonal type of the variety.

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Pollination of the Almeria Grape[1]

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THE first commercial plantings of the Almeria (Ohanez) grape made in California in the late 1870's were considered failures because of low and irregular yields. Changes in the pruning system, and fertilization, did not materially increase the yields. Finally several growers either went personally or sent agents to study the industry firsthand in Spain. Their observations indicated that artificial pollination was an important factor previously overlooked, but the necessity and reason for it are even today the subject of debate amongst these same growers.

In the Spanish districts provisions are made for artificial pollination. This is one reason why the variety is always grown on overhead arbors, about 7 feet high, and the trunk is branched horizontally in all directions on the top, to give great spread to the arms. The blossom clusters thus hang free and are easily manipulated. Many varieties are used as a source of pollen. At one time a wild male vinifera called "Flor" that was allowed to grow along fence rows and waste places furnished much of the pollen (10). After the introduction of rootstock varieties from France to combat phylloxera, many riparia and rupestris hybrids were allowed to grow without grafting, and also furnished pollen. They were referred to locally as "Parras Locas" or "crazy vines". However, of late years the Spanish growers have widely used various fruiting varieties of vinifera; a transition that has occurred because they blossom more nearly in unison with the Almeria, and are also a source of salable fruit. The variety most commonly used is the Molinera (Red Malaga of California), which in a few vineyards is interplanted or used in border rows. The term "Castiza" is used collectively to denote the whole group of vinifera varieties that are used for pollination and produce marketable fruit.

Artificial cross-pollination is generally practiced in Spain. Blossoming clusters are cut from any variety available and tied or inserted as a small bouquet at the end of a bamboo cane or stick about 3 feet long. The Almeria clusters in blossom are then rubbed or brushed with this bouquet until it is used up. When possible, the hand is placed against the cluster during pollination to prevent breakage and when withdrawn is gently passed over the cluster. Such pollination is carried on during a 15-day period, every vine being gone over every other day, which means seven or eight applications. This work is reserved for the women.

Some observers (8, 10) state that in Spain cross-pollination is unnecessary, that the important part of the operation is the mechanical dusting or rubbing of the cluster. One isolated vineyard, without any pollinating variety and no manipulation whatever, was said to produce a heavy crop of fruit (8). The evidence is therefore contradictory.

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[1] I am particularly indebted to Mr. Millard Sharpe of Vacaville, California, who spent the season of 1925 in the Almeria districts of Spain, for providing me with much detailed information on the Spanish methods of Almeria culture.

In California the pollination problem is not generally recognized. Some growers that have had long experience with the variety now alternate two rows of the Almeria with two rows of another variety in vineyard plantings, and this method has been highly successful in obtaining regular and heavy yields. However, there are some solid block plantings where no provisions have been made for cross-pollination, and the yields in many seasons are unsatisfactory. The work reported here is preliminary to field studies now being conducted in commercial vineyards on the pollination problem.

Experiments at Davis were planned to answer these questions: (a) Is the pollen of the Almeria fertile enough to result in good sets of fruit or is the variety self-sterile? (b) What is the nature of this sterility? (c) Can its own pollen when transferred artificially to the stigma effect a good commercial set of fruit? (d) To what extent may cross-pollination occur under natural conditions? (e) What are the principal agencies of pollen transfer?

The flower of the Almeria opens normally and the calyptra is shed without difficulty. Unlike self-fertile hermaphroditic varieties, the stamen filaments are very slender and very short (11). As the calyptra sheds, the stamens immediately reflex, the filaments dry up rapidly, and the anthers are appressed just under the floral receptacle. Adopting Oberle's nomenclature (4), the flower type is male sterile or "functionally pistillate". To begin with, therefore, there is the mechanical difficulty of pollen transfer from anther to stigma. The anthers do not shed pollen as abundantly as hermaphroditic varieties.

During three different seasons attempts were made to germinate the pollen *in vitro*, but without success. Over 100,000 pollen grains were cultured, and although they imbibed moisture and became fully distended, no tube growth has ever been observed. Changes in concentration of the medium, as well as addition of vitamin B_1 or yeast extract, had no effect. The pollen grains are without germ pores, as reported long ago in other varieties with completely reflexed stamens by Portele (5) and Rathay (6). Kaczmarek (2, 3), after crossing many female varieties with completely reflexed stamens, and using more than usual precaution in preventing contamination with foreign pollen, concluded that the pollen of such vinifera varieties never effects fertilization, either on selfing or crossing. Previous reports of partial fertility he ascribed to pollen contamination and faulty technique. On this basis the Almeria should therefore be completely male sterile and incapable of self-fertilization.

It has been shown repeatedly that if the clusters are bagged in manila paper bags before blossoming no set of fruit is obtained (Table II). The objection might be raised that the bagging itself has been the cause of this failure. However, if bagging is performed at the same time and good pollen is applied, the fruit set is good (Table I). The failure of flowers to set might be attributed to the mechanical failure of self-pollination. The results of pollinating the Almeria with its own pollen (Table I) shows the rather surprising results that a partial but very poor set of fruit can be obtained in this way. This might be explained by contamination with other pollen, or by some type of

TABLE I—HAND POLLINATION* OF THE ALMERIA GRAPE

Pollen	Cluster	Flowers	Seeded Berries	Per Cent Set	Compactness of Cluster
Emperor	1	259	70	27	Well filled
Emperor	2	196	27	14	Loose
Emperor	3	112	42	37	Loose
Emperor	4	162	89	55	Compact
Danugue	1	213	49	23	Loose
Danugue	2	323	105	32	Well filled
Prune de Cazouls	1	189	90	48	Well filled
319B10	1	227	93	41	Well filled
319B10	2	234	58	25	Very loose
Totals		1,915	623	32.5	
Almeria	1	862	0	0	No set
Almeria	2	945	3	0.3	Straggly
Almeria	3	436	2	0.5	Straggly
Almeria	4	648	0	0	No set
Totals		2,891	5	0.17	

*The clusters were pollinated with the finger tip, and the flowers were not emasculated. Only one application of pollen was applied at the time of full bloom, and the flowers not yet opened were removed with forceps. Both before and after pollination the clusters were kept bagged.

apomictic seed development. However, in 1933 we likewise obtained a few seeds from self-pollinating many clusters of Almeria. Three seedlings now grown to maturity resemble the Almeria parent and are unquestionably selfs. Each of these, however, differs from one another, in growth habit, in berry size, and other characters that prove that genetic segregation has occurred. Thus any recurrent type of apomictic seed development must be absent. Some Almeria pollen grains must be capable of functioning and bringing about fertilization. However, since a set of approximately 10 to 50 per cent is necessary to obtain a good commercial cluster, even thorough mechanical self-pollination would be insufficient. Observations to the contrary, either here or abroad, have apparently been in areas where some foreign pollen is present, in which case this pollen would have a better chance of reaching the stigma when the cluster is dusted with a brush or drawn through the hand.

In many of the vineyard sections throughout California the author has seen honey bees work on grape blossoms. At Davis during the entire blossoming season of 1935, honey bees in large numbers were working on the flowers, as well as the large syrphid fly (*Lasiophthicus pyrastri* Linne). On May 22, three tagged clusters in full blossom on an Almeria arbor were watched for insect visits from 9 a.m. to 12 m. One cluster was visited six different times by honey bees, and the other two were visited five times each. These were not sporadic visits, as many of the open flowers were visited. Some captured bees had very large sacs of grape pollen on their legs, and they were also collecting nectar. The pollen of these sacs was entirely from grapes, as microscopical examination proved. In some seasons the honey bees work in abundance on grape flowers; in other seasons they are rarely seen. In the spring of 1941 they were very abundant, but in the spring of 1942 very few were seen working on grape blossoms, even though the weather was suitable. At least in some seasons, the honey bee may be an active agent in cross-pollination of the Almeria grape.

Preliminary experiments performed in the spring of 1941 indicate that the wind is the more important agent in the transfer of pollen. Half of the framework of five different vines was enclosed in galvanized wire screen, five strands to the inch, before blossoming had commenced. They were situated 24 feet from the nearest vines of any other variety. The wire cages excluded bees and syrphid flies, yet allowed free movement of the air around the enclosed portion of the vines. The results given in Table II show that wind pollination is sufficient to produce fruit sets that are commercial. The results on the whole do not differ greatly from the average sets of uncaged clusters on the same vines. However, during the 1941 season many of the clusters of the Almeria grape were straggly or very loose, and these are considered unfit for good commercial packs. Since the average sets were not much greater on the clusters exposed to insect visit, it is apparent that during this season the wind was by far the most important agent in effecting cross-pollination.

TABLE II—POLLINATION OF THE ALMERIA GRAPE WHEN BAGGED, OPEN-POLLINATED, AND OPEN-POLLINATED BUT BEES AND FLIES EXCLUDED

Bagged Before Blossom				Open-Pollinated					Clusters Under Wire Cages				
Vine	Cluster	Flowers	Per Cent Set	Vine	Cluster	Flowers	Per Cent Set	Compactness of Cluster	Vine	Cluster	Flowers	Per Cent Set	Compactness of Cluster
1	1	722	0	1	3	676	22	Well filled	—	—	—	—	—
	2	1,107	0	—	—	—	—	—	—	—	—	—	—
2	1	1,602	0	—	—	—	—	—	—	—	—	—	—
	2	649	0	—	—	—	—	—	—	—	—	—	—
3	1	1,375	0	3	3	1,269	6	Straggly	—	—	—	—	—
	2	1,336	0	—	—	—	—	—	—	—	—	—	—
4	1	776	0	—	—	—	—	—	4	3	1,107	9	Very loose
	2	1,165	0	—	—	—	—	—	—	4	514	10	Loose
5	1	1,087	0	5	3	1,196	3	Straggly	—	—	—	—	—
	2	1,073	0	—	—	—	—	—	—	—	—	—	—
6	1	754	0	—	—	—	—	—	—	—	—	—	—
	2	1,413	0	—	—	—	—	—	—	—	—	—	—
7	1	1,463	0	7	3	960	3	Straggly	—	—	—	—	—
	2	1,439	0	—	—	—	—	—	—	—	—	—	—
8	1	1,540	0	—	—	—	—	—	8	3	1,320	11	Well filled
	2	1,042	0	—	—	—	—	—	—	4	887	6	Straggly
9	1	1,087	0	9	3	1,104	7	Loose	—	—	—	—	—
	2	1,392	0	—	—	—	—	—	—	—	—	—	—
10	1	862	0	—	—	—	—	—	—	—	—	—	—
	2	990	0	—	—	—	—	—	—	—	—	—	—
11	1	818	0	11	3	1,080	9	Loose	11	4	410	0	No set
	2	927	0	—	—	—	—	—	—	5	1,300	18	Well filled
12	1	1,009	0	—	—	—	—	—	—	—	—	—	—
	2	900	0	—	—	—	—	—	—	—	—	—	—
13	1	645	0	13	3	992	10	Loose	—	—	—	—	—
	2	1,302	0	—	—	—	—	—	—	—	—	—	—
14	1	325	0	—	—	—	—	—	—	—	—	—	—
	2	481	0	—	—	—	—	—	—	—	—	—	—
15	1	1,013	0	15	3	350	25	Well filled	15	4	1,208	7	Very loose
	2	1,042	0	—	—	—	—	—	—	5	1,308	5	Straggly
16	1	1,685	0	—	—	—	—	—	—	—	—	—	—
	2	687	0	—	—	—	—	—	—	—	—	—	—
17	1	1,488	0	17	3	893	22	Well filled	—	—	—	—	—
	2	741	0	—	—	—	—	—	—	—	—	—	—
18	1	436	0	—	—	—	—	—	—	—	—	—	—
	2	627	0	—	—	—	—	—	—	—	—	—	—
19	1	1,539	0	19	3	510	11	Straggly	19	4	700*	—	—
	2	1,029	0	—	—	—	—	—	—	5	771	3	Straggly
Totals		39,575	0		10	9,030	10.5			10	8,825	8.5	

*Cluster lost before harvest.

DISCUSSION

Most viticulturists have stated that cross-pollination of the vinifera grape, either by wind or insects, is a great rarity under vineyard conditions and is of no importance in commercial grape culture. [See especially the review of the German work by Sartorius (7) and also Einset (1)]. These conclusions may be valid for hermaphroditic varieties which are normally self-fertilized, and for certain vineyard districts, but in the light of the present case such generalizations are unwarranted. The efficacy or extent of cross-pollination would, of course, depend on localized conditions, such as direction, duration, and velocity of prevailing winds; the pollinizing insect populations present and the sources of food they have available; and the number, distribution, and blossoming period of other pollen-bearing varieties in the neighborhood. Due to one or a combination of the above factors, cross-pollination in a given locality may be insignificant, or it may be very important. The inherent differences between varieties must also be considered as regards the percentage of flower set necessary to yield satisfactory commercial clusters. With some varieties the percentage set only need be very low, especially if the variety has a compact blossom cluster structure of many blossoms and produces very large berries. It has been noted both here and in Rumania (9) that many female varieties with completely reflexed stamens, which fail to set when bagged, set good fruit clusters when naturally cross-pollinated under vineyard conditions.

Einset (1) stated that no female grape varieties are grown commercially in this country because natural cross-pollination is inadequate to obtain good yields. The Almeria in California is an exception to this rule. This fact brings up the question as to whether grape breeders should continue to discard all female varieties without further tests of their qualities. The experience with the Almeria in California suggests that other female varieties, if they should possess particularly desirable qualities, might be grown commercially with profit if adequate cross-pollination is provided. Since it has been observed that bees do work on grape flowers, it appears that more adequate cross-pollination may be provided for by introducing hives in commercial plantings to supplement wind pollination.

SUMMARY

The flower of the Almeria grape has completely reflexed stamens and the pollen does not germinate *in vitro*. Although some pollen grains are able to bring about fertilization, this is such a rarity that self-pollination, either naturally or artificially, does not materially affect the fruit set. The early commercial failure of this variety to fruit regularly in California can be attributed to insufficient cross-pollination. Both wind and insects are agencies in cross-pollination. Preliminary results at Davis indicate the wind is by far the more important factor. Cross-pollination of the vinifera grape may be frequent and commercially important in some localities, especially with female varieties.

Since many vineyard plantings of the Almeria have been profitable in California, it is questionable whether otherwise good vinifera varieties should be discarded or not tried commercially, simply because they are female and require cross-pollination.

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Observations on the Response of Grape Vines to Winter Temperatures as Related to Their Dormancy Requirements

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THE response of grape vines to winter temperatures is of interest not only because of its relation to winterkilling but also for the bearing it has on the adaptation of varieties to different regions. It is common observation that failure of the vines to ripen the wood properly in the late summer and fall results in the death of canes in ordinary winters, and inability of the vines to manufacture and store sufficient reserves during the growing season probably accounts for the failure of the less hardy varieties to withstand the low temperatures of more severe seasons. But there is another phase of their responses to winter temperatures that is less understood and on which little appears to have been written, namely, the duration of low temperatures necessary to meet their dormancy requirements. Thinking that this might have something to do with the failure of standard northern varieties to thrive in many southern areas, an experiment was set up in the fall of 1940 at the United States Bureau of Plant Industry Station, Beltsville, Maryland, to see what the nature of the reaction of northern, intermediate, and southern standard varieties would be to different periods of exposure to winter temperatures, in the hope that some light might be thrown on this problem of inadaptation.

The plants used in this experiment were those made available by the termination of the work on aerial propagation reported to this Society in 1940 (4). There were 123 plants in all, representing nine varieties. This number was smaller than desired for a really satisfactory test, particularly with some of the southern varieties, but the experiment was intended to be merely exploratory in character and it was thought best to use the material immediately at hand. The identity and the number of plants of each were as follows: Dakota (hardy northern), 18; Delaware and Niagara (intermediate), 18 each; Concord and Peabody (also intermediate), 16 each; Bailey, Ellen Scott, and Beacon (southern), 8 each; and Herbemont (also southern), 13. These had been growing in the open in 11-inch clay pots plunged into the soil during the summer. They were pruned after the leaves had fallen in the early winter.

Summations of temperature below 45 degrees F and variable exposure periods were used as criteria. At the end of each exposure period selected groups of plants were removed to the greenhouse, having a temperature varying from 60 to 70 degrees F. In the case of the hardier varieties the exposure periods were increased from 200 to 1400 hours by 200-hour increments. In the case of the southern varieties 100-hour increments for periods ranging from 200 to 800 hours were used. The minimum temperature of the season was 6 degrees F. The response of the plants to these treatments was recorded as the number

TABLE I—EFFECT OF DIFFERENT PERIODS OF EXPOSURE TO OUTDOOR WINTER TEMPERATURES BELOW 45 DEGREES F ON GRAPE PLANTS, RECORDED IN TERMS OF THE NUMBER OF DAYS REQUIRED FOR NEW GROWTH TO APPEAR AFTER PLACING IN THE GREENHOUSE (GREENHOUSE TEMPERATURE 1940–41, 60 TO 70 DEGREES F; 1941–42, 65 TO 75 DEGREES F)

Approximate Exposure Period	200 Hours		300 Hours		400 Hours		500 Hours		600 Hours	
Year	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42
Actual Exposure	206	206	313	312	396	396	521	511	612	623
Variety										
Dakota	86, 93, 93 (91)*	56, 55, 54 (55)	—	—	52, 56, 65 (58)	48, 49, 49 (49)	—	—	49, 49, 49 (49)	24, 35, 35 (31)
Concord	86, 93 (90)	54, 60 (57)	—	—	54, 78 (66)	47, 47 (47)	—	—	36, 43 (40)	34, 34 (34)
Delaware	86, 93, 93 (91)	62, 68, 68 (66)	—	—	65, 74, 81 (73)	49, 49, 55 (51)	—	—	65, 65, 65 (65)	42, 42, 53 (46)
Niagara	86, 93 (90)	60, 63 (62)	—	—	56, 74 (65)	49, 53 (51)	—	—	49, 49, 52 (50)	41, 41 (41)
Peabody	80, 93, ?** (87)	37, 39, 38 (38)	—	—	36, 49, 53 (46)	33, 33, 33 (33)	—	—	43, 49, 49 (47)	25, 31, 36 (31)
Bailey	71, 86 (79)	45, 45 (45)	62, 62 (62)	53, ?**	56, 65 (61)	55, 44 (50)	43, 56 (50)	38, 39 (39)	—	—
Ellen Scott	No growth	D†	113	44	91	53	101	39	D†	—
Beacon	145	78	122	61	91	55	101	47	75	50
Herbemont	48, 48, 61 (52)	64, 64, 75 (68)	52, 55, 62 (56)	54, 60, 68 (61)	49, 52, 65 (55)	49, 54, 60 (54)	65, D, D†	47	58	41

Approximate Exposure Period	700 Hours		800 Hours		1000 Hours		1200 Hours		1400 Hours	
Year	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42	1940-41	1941-42
Actual Exposure	710	708	806	784	1024	1001	1200	1198	1409	1422
Variety										
Dakota	—	—	34, 43, 49 (42)	25, 26, 26 (26)	42, 42, 42 (42)	19, 21, 20 (20)	28, 34, 34 (32)	23, 28, 28 (25)	—	—
Concord	—	—	40, 43, 49 (44)	31, 32, 31 (31)	42, 42, 42 (42)	30, 30 (30)	34, 34 (34)	28, 28 (28)	27, 31 (29)	22, 22 (22)
Delaware	—	—	56, 56, 56 (56)	41, 41, 41 (41)	36, 49, 53 (46)	30, ?, ?**	41, 41, 51 (44)	29, 29, 29 (29)	—	—
Niagara	—	—	43, 43, 56 (47)	33, 33, 42 (36)	36, 42, 49 (42)	20, 28, 28 (25)	34, 34, 36 (35)	22, 28, 28 (26)	30, 30 (30)	21, 21 (21)
Peabody	—	—	43, 64, 69 (59)	22, 24, 24 (23)	36, 42, 42 (40)	21, 21, 21 (21)	28, 28 (28)	22, 22 (22)	—	—
Bailey	—	—	—	—	—	—	—	—	—	—
Ellen Scott	60, D†	42	D†	—	—	—	—	—	—	—
Beacon	60, D, D†	44	—	—	—	—	—	—	—	—
Herbemont	—	—	—	—	—	—	—	—	—	—

*Figures in parentheses indicate averages. **Growth very long delayed. †Dead.

of days required in the greenhouse for the first greening of buds to be apparent.

When danger of spring frosts was past the plants were taken from the greenhouse and the pots plunged into the soil as before. The plants were given a light uniform application of nitrate of soda and such watering and tending during the season as was necessary to keep them in vigorous condition. In the fall and winter of 1941–42 the treatment of the previous year was repeated, taking care that the plants of each exposure group were identical with those of the 1940–41 test. The only difference in the treatment of the vines in this case was that the minimum temperature of the season was —3 degrees F and the greenhouse temperature was held at 65 to 75 degrees F, which was 5 degrees higher than during the previous season. This was done to meet the requirements of other experiments being conducted by other workers under the same roof. The findings for the two years are presented in Table I and illustrated in Figs. 1 and 2.

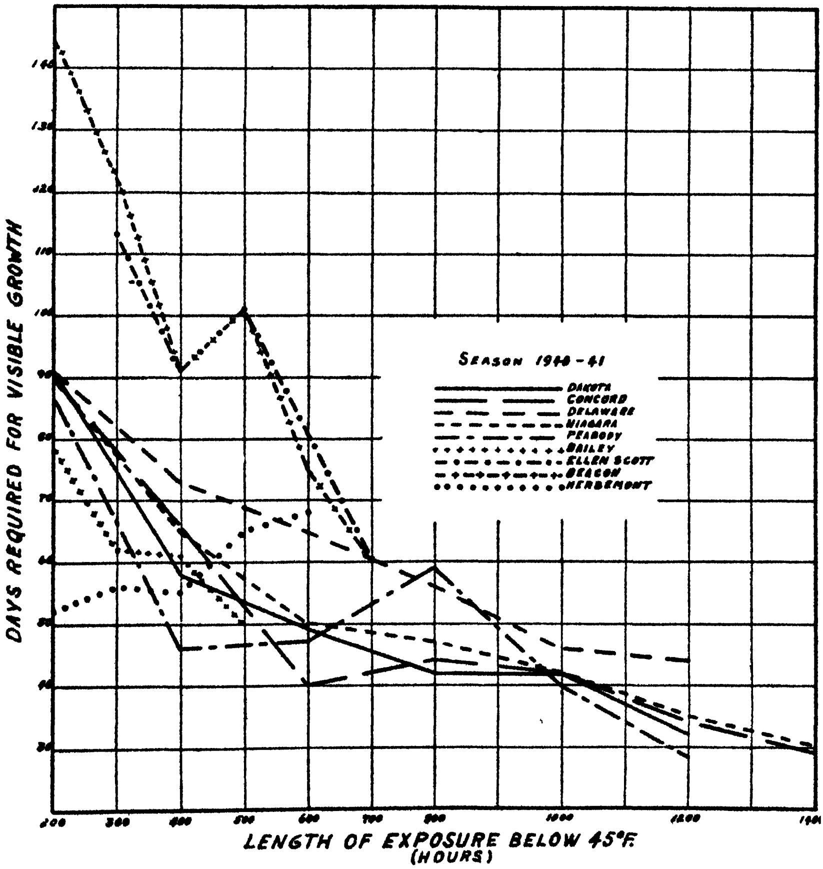

FIG. 1. Curves showing the reduction in time required for the initiation of foliation of grapes with increased exposure to temperatures below 45 degrees F. Season of 1940–41.

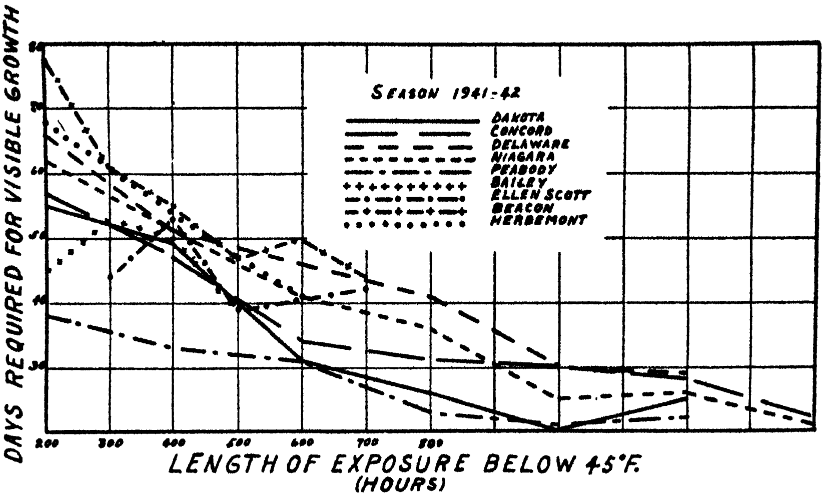

FIG. 2. Curves showing the reduction in time required for the initiation of foliation of grapes with increased exposure to temperatures below 45 degrees F. Season of 1941–42.

Considering first the results of the 1940–41 test, it is noted that with none of the varieties tested was an exposure period of 200 hours below 45 degrees F too short to prevent foliation. With the Dakota, Concord, Delaware, Niagara, and Peabody, initial growth appeared within a period of 87 to 91 days after moving into the greenhouse. With longer exposures the time required for beginning foliation was very materially reduced, the period ranging from 28 to 45 days after 1200 hours of exposure. In the case of Concord and Niagara, which were held for 1400 hours, 29 to 30 days were required. Bailey, of the southern group, behaved in a similar manner but was a little more prompt in initiating growth, 79 days being required after an exposure of 200 hours and 50 days after an exposure of 500 hours. Unfortunately, lack of plants prevented a further reading on this variety. Beacon and Ellen Scott, also of the southern group, were much slower in responding to the greenhouse conditions. The 200-hour plant of Ellen Scott failed to develop at all, though it appeared to be alive when brought inside. Beacon required 145 days to initiate foliation after 200 hours of exposure, but both this variety and Ellen Scott showed very marked shortening of the time required for beginning growth as the exposure periods were increased. Unfortunately, plants were not available to continue observations on these varieties beyond the 700-hour exposure period. At the end of this time both showed initial foliation at the end of 60 days. Herbemont, the remaining southern variety, behaved entirely differently throughout the test. It initiated growth in 52 days after exposure for 200 hours, but as the exposure periods were increased in length the plants responded less promptly, those exposed for 600 hours requiring 68 days to show beginning growth.

In the light of results obtained the following season with these same plants, it is believed that the aberrant behavior of the Beacon, Ellen

Scott, and Herbemont varieties was due primarily to the fact that being normally late maturing and having been but recently propagated they had not had sufficient time at the beginning of the test to mature their wood properly. This is evidenced by the fact that some plants of all three varieties were lost by winterkilling. However, Beacon and Ellen Scott seemed able to adjust themselves somewhat as the winter progressed, while the plants of the Herbemont appeared to become progressively weaker.

It is probable that the small number of plants entering into the test accounts in part for the irregularity of the curves.

It should be noted that once growth had been initiated, foliation proceeded promptly and normally in all cases, both during this and the following season's tests.

In the 1941–42 tests, it is seen that while there are some irregularities in the curves, due doubtless to the small number of plants involved, the widely aberrant findings of the previous season do not appear. There were differences in the behavior of different varieties, to be sure, but the general picture was the same, in that as the length of the exposure period was increased there was a progressive shortening of the time required for the plants to initiate growth. Here again, as in the previous season, there was no evidence that a 200-hour exposure at temperatures below 45 degrees F was too short a time to prevent foliation. An exposure of 1000 to 1200 hours appeared to satisfy all needs. It is to be noted that in all cases initiation of foliation took place in a shorter time than during the 1940–41 tests, which it is believed was in part if not wholly due to the somewhat higher greenhouse temperatures of the 1941–42 season.

The annual low-temperature needs of Eastern bunch grapes seem to be somewhat less than those of other standard American fruits. The work of Hutchins (3) and of Weinberger (5) in Georgia, and of Yarnell (6) in Texas has shown that, depending on variety and location, exposures to temperatures below 45 degrees F for 400 to 1200 hours are required to break the rest period of peaches. Most varieties of blueberries, according to Darrow (2), require a minimum of 800 to 1060 hours below 45 degrees F, and the chilling needs of apples are known to be even greater. The present findings, which are in accord with the reported observations of Chandler, *et al.* (1) in California, indicate that the Eastern bunch grapes can get along, for a time at least, with 200 hours or less of exposure to 45 degrees F, though they respond more promptly to favorable growing temperatures as the period of chilling is increased. From this it would appear that the shortness of the rest period is probably of minor importance as affecting the longevity of northern grapes grown under southern conditions. The cumulative effects covering a more extended period, however, may be of some significance.

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An Evaluation of the Use of French Hybrid Wine Grapes in Breeding Hardy Grapes for the Eastern United States[1]

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THE production of improved types of hardy grapes for the eastern United States has, in the past, involved the use in hybridizing programs of varieties of *Vitis vinifera,* the European wine grape. Accounts of these methods have been given by Wellington (5, 6, 7, 8), Stout (3), Munson (1) and others. Useful as the wine grape has been in this respect and though noteworthy the results obtained by these workers as shown by the list of varieties having *V. vinifera* as a parent which have been introduced by them, nevertheless there are limitations to the use of this species. It lacks hardiness, is susceptible to insects and diseases prevalent in America and is far more exacting as to cultural and environmental requirements than are the American species of grapes and the varieties derived therefrom. Though the quality of the fruit of a hybrid may be immeasurably improved by incorporating a variety of *V. vinifera* in its parentage, the shortcomings of that species are likewise accentuated therein. For this reason many seedlings which bear fruit of excellent quality and comparable to the European parent have vines which are lacking in hardiness, stamina, vigor and resistance to diseases and insects. Of course genetic principles governing segregation and recombination of characters should enable one to produce individuals possessing only the desirable characteristics of both parents and very few of the undesirable ones. However, the laws of chance which are responsible for such segregations and recombinations require that tremendous populations of such hybrids be grown because of the large number of characters concerned and the probably numerous factors governing them. Wellington (7) has stated that the proportion of vinifera characters in a given individual cannot safely make up more than 75 to 85 per cent of its constitution for areas having minimum winter temperatures of —15 degrees F or below. Dilution beyond this point is certain to result in lack of winter hardiness and stamina. Since many of the varieties of American grapes which might be used as parents in a breeding program already are attentuated hybrids of *V. vinifera,* there are limitations to the results which may be expected from backcrossing to vinifera parents. Selfing such hybrid material has resulted in such a high proportion of weak offspring that at this Station outcrossing to distantly related types is considered preferable.

A valuable source of breeding material which has received but scanty attention in America is the assortment of hybrid grapes produced by French and German viticulturists of a generation ago in their search for "producteurs-directs" or "direkte träger". Among these workers were M. Seibel, C. Oberlin, L. Bouschet, M. Baco, A. Millardet, L. Ravaz and many others as listed by Viala and Vermorel (4). Their work was motivated by the same desires underlying much of our American grape breeding program, namely, to develop individuals bearing fruit of vinifera quality and character on vines having the stamina, hardiness and resistance to pests of the American species. Impetus was given to their work during the latter part of the nineteenth century by the appearance in European vineyards of such American pests as the phylloxera, powdery mildew and downy mildew which threatened destruction to the vineyards of that continent. Though discovery of other methods of combatting these pests has made less evident the partial success and accomplishment of their objectives, nevertheless their contribution to the world's viticulture has been a considerable one. The breeding work undertaken by these workers involved hybridization of American species of Vitis with varieties of vinifera grapes. Though even the best of their hybrids have been considered inferior in quality to European sorts and are not widely grown in areas which can successfully grow the vinifera grape, many of them have proved to be of value in areas not suitable for the latter. Moreover they constitute a valuable source of breeding material which should not be overlooked. Since many of these varieties are less distantly removed from the American and European species than many American varieties, they possess more of the desirable characteristics of both parents in less attenuated form than many of the American produced varieties.

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[1] Journal Paper No. 540, New York State Agricultural Experiment Station, Geneva, N. Y.

A number of such hybrids, most of which are designated by the seedling or selection number of the hybridizer coupled with his name, have been under test at the New York State Agricultural Experiment Station for a number of years. Though the majority of them proved to be unsatisfactory for general cultivation in New York, two have shown sufficient quality for wine making purposes to attract the attention of several wineries. Small acreages of Seibel 1000 and Seibel 6339 are now being grown in this state for that purpose. However some of the hybrids may yet make an even greater, though indirect, contribution to American viticulture in the role of parents in the grape hybridization program being conducted at the Experiment Station.

In 1932, Professor R. Wellington made a number of grape crosses involving Seibel 4646, Seibel 5437, Seibel 5898, Seibel 6339, Seibel 6905, Commandant (Bertille Seyve 2862), and Bertille Seyve 2667. These were crossed with Seneca, Brocton, Yates, Ontario, Fredonia, Kendaia and Elvira.

Seneca, Ontario and Elvira are early season white grapes. Fredonia and Kendaia are early season, blue fruited Labrusca types. Brocton bears white fruit ripening in the Concord season while Yates is a red variety ripening in season with Catawba.

Most of the seedlings developed from these crosses have fruited and have been evaluated for selection and propagation. Further testing and evaluation based on a larger number of plants is now in order. Sufficient information has been obtained to permit publication of a report summarizing the observations and progress to date.

Since characteristics such as winter hardiness, resistance to diseases and insects, vigor and productivity are difficult to evaluate, no numerical data are presented here concerning these items. In general the winter hardiness of these seedlings has appeared to be satisfactory. Though some seedlings have failed to survive and some have been killed to the ground by winter freezes, the populations as a whole have been the equal if not superior to populations resulting from other crosses. They are definitely superior in hardiness to crosses involving a variety of *Vitis vinifera.* However prior to the winter of 1942–43 they had not been subjected to a really severe temperature test. Their reaction to the freeze of December 20, when minimum temperatures of —18 degrees F were recorded, should give more information concerning the relative hardiness of the individual seedlings.

The reaction of this lot of seedlings to attacks by downy mildew and grape leaf hopper has shown nothing unusual, with the exception of the Fredonia crosses all of which showed great susceptibility to downy mildew. This tendency has been previously noted in other crosses involving Fredonia. Some injury from these pests was noted but many individuals showed less injury than many of the standard varieties growing in adjoining vineyards. A late season infection by powdery mildew in 1942 caused injury ranging from slight to almost complete defoliation. These vines have never received sprays or dusts of any type.

The vigor of this lot of seedlings was exceptional. This has been attributed to the fact that most of the French hybrids incorporate in their makeup considerable of the characteristics of *Vitis rupestris, V. riparia* and *V. aestivalis.* These species, or varieties derived therefrom, have not been used to any extent in the breeding program of this station. Therefore the crosses herein described, with the exception of the Elvira x Seibel 6905 seedlings, represent the union of distantly related genic entities. As a result considerable heterosis or hybrid vigor might be expected.

Productivity of the lot has been widely variable from year to year. However many seedlings have borne crops equaling or surpassing those of any other individuals under test at the station. Overbearing has undoubtedly weakened some vines and been responsible for the winter injury which subsequently appeared.

The data and observations on these progeny have been summarized and are presented in Table I. Analysis of these data indicates several interesting features. As shown in an earlier publication (2) Seneca seems to be homozygous for the functionally hermaphroditic character in that practically all of its seedlings are functionally hermophroditic. Ontario, Yates, Fredonia, Kendaia, Brocton, Seibel 6905, Seibel 5898, Seibel 4643 and Commandant are heterozygous for this character in that combinations involving these parents give some functionally pistillate offspring.

Bertille Seyve 2667 appears to be homozygous for the black fruit color in that only one white seedling appeared in its progeny. Most of the crosses involving a black and a white parent gave approximately half black and half white fruited seedlings. Red seedlings appeared with any degree of frequency only in the progeny of Yates, a red variety, and of Fredonia and Kendaia.

The appearance of teinturier types or those with fruit having pigmented juice shows some interesting segregations. Seibel 5437 and Seibel 6339 gave a very high proportion of teinturier types among their black-fruited seedlings. Commandant, Bertille Seyve 2667, Seibel 5898 and Seibel 6905 gave a smaller proportion of teinturier types, while Seibel 4643 gave only one weakly pigmented seedling in a population of 249. The teinturier characteristic appears to be correlated with red autumnal coloration of foliage. The non teinturier types appeared to show only yellow autumnal coloration of the foliage.

Fruit quality is a difficult character to evaluate. However figures are presented which give some indication as to the comparative degrees of quality exhibited by the various progeny. The ratings of quality given in Table I are based on juice sugar content as determined with the Zeiss hand refractometer, titratable acidity and freedom from marked objectionable flavors or aromas which could be detected organoleptically. Wine-making tests will be made of seedlings selected for further testing when propagations of the latter reach bearing age. In general the seedlings of Seneca were given higher ranking than those of other crosses. Crosses of Fredonia, Kendaia, Yates and Elvira showed a higher proportion of poor quality seedlings. Many of the Yates seedlings undoubtedly received low ranking because they were so late in ripening that they had little chance to develop quality. Seedlings of Ontario showed a wider range in respect to quality than did the progeny of other crosses. Seedlings of Seneca showed no marked foxy or labrusca flavor. This might be expected since neither Seneca nor the French hybrids used show any degree of labrusca characteristics. Riparia and aestivalis flavors were noted in many seedlings. The seedlings of Ontario, Fredonia and Kendaia showed many more

TABLE I—A SUMMARY OF THE CHARACTERISTICS OF THE SEEDLING GRAPES FROM CROSSES OF FRENCH WINE HYBRIDS

Cross	Flower Type		Fruit Color			Teinturier Types	Fruit Quality			Season of Ripening			Number of Seedlings Selected for Further Test
	⚥	♀	Black	Red	White		Good	Fair	Poor	Early	Medium	Late	
Seneca × Commandant	13	—	5	1	7	1	1	11	1	—	3	10	—
Commandant × Seneca	87	—	42	—	45	22	22	53	12	26	41	20	8
Seneca × Seibel 6339	40	—	20	—	20	12	10	26	4	15	19	6	4
Seibel 6339 × Seneca	114	—	63	—	51	56	39	59	16	42	48	24	14
Seibel 5437 × Seneca	117	1	59	—	59	52	39	60	19	45	51	22	19
Bertille Seyve 2667 × Seneca	54	—	53	—	1	11	18	28	8	8	30	16	15
Seibel 6905 × Elvira	30	3	17	2	14	10	6	13	14	4	19	12	—
Ontario × Seibel 6905	53	8	37	1	23	3	13	36	11	17	34	10	4
Commandant × Yates	70	21	44	25	22	20	5	55	31	—	23	68	—
Seibel 5898 × Fredonia	19	3	14	8	—	3	—	10	12	3	19	—	—
Seibel 6905 × Fredonia	7	5	5	7	—	—	1	7	4	1	7	4	—
Seibel 6905 × Kendaia	38	9	31	6	10	1	2	31	13	2	17	28	1
Seibel 4643 × Ontario	187	63	125	1	124	1	37	153	60	31	194	24	2
Brocton × Seibel 6905	12	1	7	—	6	—	7	6	—	1	7	5	2

examples of foxiness than any of the other crosses. Riparia and aestivalis flavors were noted but were not as striking as the labrusca flavors. Elvira and Yates crosses also produced some labrusca flavored seedlings. The proportion of clean, vinous flavored seedlings was greater by far in the Seneca seedlings. The comparative quality of the various crosses is well portrayed by the number of individuals selected for further testing from the seedlings of Seneca crosses as contrasted with the few selections from the other crosses.

In brief the varied assortment af European wine hybrids offers a valuable source of breeding materials in that these individuals already represent the results of much breeding effort and years of selection. Combining the best of those with better American sorts may well be expected to give both wine and table sorts adapted to American conditions and which will be superior to any at present available.

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The Influence of Time and Method of Pruning on Yields of Muscadine Grapes

By N. H. Loomis, *U. S. Department of Agriculture, Meridian, Miss.*

MUSCADINE grapes bleed very severely if pruning is delayed much after defoliation in the fall (4, 6). The length of time after leaf fall during which the vines may be pruned without bleeding varies with weather conditions and has been observed to be as short as two weeks. After this period the bleeding gradually increases with the delay in pruning and becomes very severe if pruning is done just before the buds swell. The statement has frequently been made by growers that the vines will be injured by severe bleeding, and many research workers (1, 3, 5) have recommended that the vines be pruned early so as to avoid bleeding. At least one worker has concluded that the bleeding is of little importance (2).

Most investigators have also recommended spur-pruning rather than cane-pruning for a greater yield of muscadine grapes; however, there are few published records comparing yields from spur- and cane-pruned vines.

In order to study these two problems, an experiment was initiated at the United States Horticultural Field Station, Meridian, Mississippi, in the winter of 1939–40. Six-year-old Scuppernong and Thomas vines were selected for the experiment. These were set 15 feet apart in 10-foot rows in a planting which consisted of one-ninth staminate vines. Each row consisted of 10 vines but the number suitable for experimental work varied from 5 to 10 per row.

Spur pruning as done in this experiment consisted of shortening the new growths to spurs of about four buds each and thinning them so they were about 3 inches apart. The cane pruning consisted of a six cane kniffen system with the canes 7½ feet long. In 1942 the systems were slightly modified as noted later in the text in order to equalize the number of buds left on the vines after pruning.

The experiment with Scuppernong consisted of four rows divided so that the first year two rows were pruned in November, shortly after leaf fall, and two in March, just before foliation when bleeding is extremely severe. At each date one row was spur-pruned and one cane-pruned. This procedure was repeated the following winter, except that the early pruning was done in December instead of November because defoliation was later. In the third winter, 1941–1942, only 16 Scuppernong vines were used; these were divided into eight pairs and were pruned in December. One vine of each pair was spur-pruned and the other cane-pruned. The number of buds left on each pair of vines was the same, so that differences in yields would be due to the type of pruning rather than to a difference in the number of buds left. No attempt was made during the two previous years to balance the number of buds left on the spur- and the cane-pruned vines, respectively.

The experiment with Thomas grapes also consisted of four rows.

The first year of the test three rows were pruned in November, two by the cane method and one by the spur method, and the fourth row was cane-pruned in March. The following winter these four rows were pruned the same as the Scuppernongs, two early and two late, and at each pruning date one row was spur-pruned and one cane-pruned. No further work was done on Thomas grapes after the second year, 1940–41.

The results of the experiments are presented in Table I.

TABLE I—EFFECT OF EARLY AND LATE PRUNING, AND OF SPUR- AND CANE-PRUNING ON YIELD OF MUSCADINE GRAPES GROWN AT THE UNITED STATES HORTICULTURAL FIELD STATION, MERIDIAN, MISSISSIPPI

Variety	Type of Pruning	Yield (Pounds)		
		1940	1941	1942
Scuppernong	Pruned early			
	Cane-pruned	9.3 ±0.82*	12.7 ±1.62*	23.9 } †
	Spur-pruned	24.0 ±3.92	47.7 ±4.33	42.4 } ±4.69
Scuppernong	Pruned late			
	Cane-pruned	11.9 ±2.00	17.0 ±3.07	—
	Spur-pruned	30.1 ±1.73	51.7 ±2.17	—
Thomas	Pruned early			
	Cane-pruned	8.3 ±0.63	18.6 ±1.63	—
	Spur-pruned	24.1 ±2.93	53.6 ±8.21	—
Thomas	Pruned late			
	Cane-pruned	8.9 ±1.04	18.0 ±1.16	—
	Spur-pruned	—	42.6 ±3.02	—

*Standard error of unpaired vines.

†Standard error of difference of eight pairs of vines The number of buds on each member of a pair after pruning was the same.

DISCUSSION

On similarly pruned vines there were no significant differences in yield due to time of pruning. For all vines pruned at the same time the differences in average yield per vine in favor of the spur-pruning were highly significant, and ranged from 14.7 to 35.0 pounds.

The test using paired Scuppernong vines having the same number of buds was begun after two years' results. It was necessary to use two to three times as many canes as formerly on the cane-pruned vines in order to have as many buds as on the spur-pruned vines, and it was also necessary to shorten the length and reduce the number of spurs on the spur-pruned vines as compared with normal spur-pruning. This was reflected in the 1942 yields, which in the case of the cane-pruned vines were almost double the yields of the previous year, and in the case of the spur-pruned vines were reduced about 11 per cent.

In the spring of 1939 sap was collected from James and Thomas muscadine vines, and two analyses were made of the sap of each variety. The James gave no reading for reducing sugar or for total sugar. This was also true of one sample of the Thomas sap; but the other sample showed a trace of reducing sugar and 0.04 per cent total sugar. The amount of soluble solids in all cases was too small to give any reading on the refractometer.[1]

SUMMARY

In a test at Meridian, Mississippi, on the muscadine grape varieties Scuppernong and Thomas, conducted between 1939 and 1942, no significant differences in yield were obtained between vines pruned soon after leaf fall and vines pruned just before the buds began to swell in the spring. The spring pruning caused severe bleeding whereas the early winter pruning resulted in little or no loss of sap. Chemical and refractometer analyses indicated that the sap consisted practically entirely of water. The yield records tended to confirm the conclusion that no considerable amount of plant nutrients was lost through bleeding.

Spur-pruning gave from 14.7 to 35.0 pounds more fruit per vine than cane-pruning; and even when the number of buds on each pruning treatment was the same, the yields were 18.5 pounds per vine greater from spur-pruned vines. The differences in yield due to the method of pruning were highly significant in all cases.

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[1] Grateful acknowledgment is made to Dr. J. M. Lutz for his assistance in analyzing these samples.

Initial Results From Grape Fertilizer Plots

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THE past miscellaneous experiments with grape vineyards in California have given no definite evidence of yield response to phosphate or potash applications although there is perhaps one exception in the latter case. It has seemed most economical of time and expense, therefore, to test the response to nitrogen alone and to a combination of nitrogen, potash, and phosphate. If the combined fertilizer yields additional response over that of the nitrogen alone, further tests are to be instigated to ascertain the relative roles of potash and phosphate.

Practical considerations seem to prohibit error control by the use of the randomized block or of the Latin square methods. Theoretically and practically, comparison of an elongated fertilized row with the average of two check rows on either side largely compensates for soil variation in both directions. Further, in order to partly compensate for variations in cultural operations, such as thinning and pruning, a check lot was introduced in every row. The plot layout consisted then of a systematic alternation of treatment and check lots. The results were statistically evaluated by Student's pairing method, using Fisher's t-table.

Normally six replications of an N treatment, six of NPK interspersed with 12 check lots, each of 20 or more vines, were utilized. In some cases soil variation and the small size of the vineyards have allowed only half this number of replications.

Since potash and phosphate are commonly fixed in soils (1), even extreme applications (2) may not serve to supply deciduous fruit trees sufficiently. For this reason an application rate was selected which goes well beyond practical application unless remarkably favorable results are obtained. For the NPK treatment 3½ pounds per vine of a salt mix of approximate analysis 4.6–18.6–21.7, containing the nitrogen as ammonium phosphate, was applied. This amounts to 1,500 to 2,100 pounds per acre, depending upon the planting distances. For the N treatment ¾ pound of ammonium sulfate (21 per cent N) per vine was utilized. The fertilizer was distributed in bands in furrows on both sides of the vines (18 to 30 inches away). The furrows were turned deeply enough to cut a number of roots. It was hoped that new root growth would circumvent the nonmobility and fixation of the P and K. The applications were made in March, 1941, about the time new shoot growth began.

Box or raisin tray counts served for crop records. Proebsting, (unpublished data) finds such a procedure justifiable. Large signs placed at the beginning and end of each treatment were used as temporary recording points, particularly in the table grape vineyards which are commonly picked over two to four times.

Shortly prior to harvest, cluster counts were obtained in order to ascertain the vine to vine to vine variability, to check on the harvest records and to detect diseased or otherwise injured vines. At this time, samples consisting of entire clusters sufficient to fill a 28-pound box were taken by removing the first convenient, approximately normal cluster from a particular section of the vine. The sample clusters were removed rapidly, and knowledge of the treatment avoided in order to obtain an unbiased sample.

The clusters were counted and weighed in order to obtain an average cluster weight. Small sections were clipped out of the top, middle, and bottom of each cluster. The berries from these sections were removed from the stems and four lots of 200 berries were counted and weighed in order to find the average berry size. If reasonably close checks were not obtained, further lots were counted. In the case of colored varieties, one kilogram of the berries was weighed out for color extraction. These berries were placed in a 6-liter flask and 1 liter of 20 per cent ethyl alcohol 0.1 normal in HCl was added. The flasks were placed on electric hot plates regulated so that the solution boiled in 20 minutes and simmered at low heat for 15 minutes. A suitable aliquot of the cooled and filtered extract was acidified with 2 ml of 1 + 1 HCl and diluted to 100 ml. A modified Evelyn photoelectric colorimeter, with Eastman Kodak Company No. 430 and 338 filters, served to determine the color density. No absolute standard was utilized, as the figures are used comparatively only.

The juice was extracted from the cluster residues and a Balling hydrometer used to ascertain the soluble-solids content of the juice. The acidity was determined by titrating a 10-ml aliquot of the juice with 0.133 N NaOH with phenolphthalein as the indicator.

The prunings from each replica lot were collected and weighed as these weights should give an accurate measure of the vine growth, since a high percentage of the new shoot growth is removed each year at pruning time. The small increments in annual circumference increase of the older vines, together with the difficulties introduced by bark loosening, make trunk measurements somewhat unsatisfactory.

RESULTS AND DISCUSSION

The data presented in Table I are all expressed as the percentage increase (+ figures) or decrease (— figures) of the fertilized plots over or under the check plots. Thus the figure of +14.6 means that compared to a check yield of 100 the fertilized yield was 114.6.

It appears that the nitrogen treatment has resulted in significant response (odds over 20: 1) in only two of the plots; however, the positive results obtained in all except one plot gives a significant average yield increase of 9.4 per cent. The addition of potash and phosphate to the nitrogen has depressed the effect of the latter so that the average yield increase is only about half that of the nitrogen alone. Considering the relative mobility of the nitrogen after nitrification of the ammonia has taken place, it appears doubtful if the depressing effect of P and K addition can entirely be ascribed to anion competition of phosphate and nitrate.

Berry size differences averaged to small positive increases for both treatments, which are not statistically significant. It seems probable that the crop increases were largely brought about by an increased berry set. Proebsting (3), for example, has found nitrogen to increase the percentage set on the Bartlett pear.

The soluble-solids content or Balling hydrometer reading is an indication of the sugar content which is largely used as a grape maturity standard, although the Balling-acid ratio seems to be superior (4). It appears that the maturity of the grapes has been delayed slightly by both the N and NPK treatment, since the Balling reading is slightly decreased and the acid increased. In both instances the general averages are significantly different from the check averages

TABLE I—COMPARISON OF GRAPE FERTILIZER TEST PLOT RESULTS (FALL 1941) EXPRESSED AS PERCENTAGE CHANGE FROM CORRESPONDING CHECK LOTS

Cooperator and County	Soil	Variety	Yield		Berry size		Balling		Acid		Color		Pruning weights	
			N	NPK	N	NPK	N	NPK	N	NPK	N	NPK	N	NPK
* Hummel Napa Co.	Butte stony loam.	Grand noir	+14.6	-0.5	-0.8	-2.8	+10	+2.0	-3.4	0.0	-13.8	-3.4	—	—
Johant San Joaquin	Madera loam.	Tokay	+14.9	+6.6	-14	-12	-26	-2.2	+5.1	+5.1	-22.0	-27.0	+2.0	+3.5
* Hoobesland San Joaquin	Hanford fine sandy loam.	Tokay	+24.0	+10.5	+3.4	+9.2	-3.1	-5.3	+4.3	+5.0	-29.4	-26.5	-7.7	-8.3
Arakelian Madera	Oakley and Fresno sands undiff.	T.S.	+4.4	+4.7	+11	+19	-17	-0.3	+0.9	+2.4	—	—	-3.0	+1.1
Shattuck Fresno	Fresno sandy loam.	T.S	+16.6	+3.0	+4.0	+4.5	-19	-15	0.0	+3.6	—	—	+4.9	-1.0
* Barr Fresno	Madera sandy loam.	Emperor.	+9.1	+14.1	+5.5	+0.5	0.0	-0.8	+5.8	+5.2	0.0	-3.2	+12.8	+10.4
* George Tulare	Madera sandy loam.	T.S.	-4.6	+2.3	+13	+17	-3.1	-4.4	+6.6	+6.6	—	—	—	—
Dobson Tulare	Madera sandy loam.	Emperor	+9.1	+7.3	-18	-0.1	+0.4	-0.4	+3.8	+2.6	-7.0	+3.4	+0.1	+8.2
Carotan Kern	Hanford sandy loam.	T.S.	+6.9	+2.1	+6.1	0.0	-3.0	-0.3	+4.9	+3.9	—	—	+3.7	+0.5
Delano Fruit Kern	Hanford sandy loam	Malaga	+2.5	-6.0	-4.3	+2.2	-0.4	-13	+9.9	+11.4	—	—	-2.5	+7.2
Weller Kern	Hanford sandy loam.	Ribier	—	—	-0.5	+13	-10	-2.5	+18	+4.6	+17.5	+12.5	-3.9	-4.1
Weller Kern	Hanford sandy loam.	Molinera	+6.2	+6.8	-0.8	+0.6	+10	-0.8	-0.5	+3.5	+4.7	-0.6	+8.4	+6.6
Walker Kern	Hanford sands	Ribier	+9.0	+2.6	—	—	-6.8	-3.3	+17.5	+8.3	-19.2	-15.3	+5.0	+8.2
Average result			+9.4	+4.5	+1.0	+15	-16	-1.6	+4.4	+4.8	-8.7	-7.5	+1.8	+2.9

* - only three replications

Note: Underlined figures have statistically significant differences even though the effect is ordinarily too small to be of practical importance, representing a harvest delay of 1 to 3 days.

In two vineyards both N and NPK applications have interfered significantly with color development. The grapes on the Weller Ribier plot were badly mildewed, which may well account for the seemingly anomalous increased color content of the fertilized plots; at any rate, the color extracts for individual lots gave extremely irregular values fluctuating above and below the corresponding check lots, contrary to the results from the other plots. If this plot were disregarded, the general average color content would be significantly lower than the check lots in the case of the N application. None of the growers detected color differences in their examination of fruit harvested from the check and fertilized lots. It seems that the greater sensitivity of the extraction procedure may detect differences which are not particularly obvious visually.

Contrary to the expectation arising from the numerous reports in the literature of greatly increased terminal growth in deciduous fruits as a result of nitrogen application, there seemed to be little, if any, general increase in the vine shoot growth as the result of the fertilizer application. Seemingly the crop was more greatly favored by the fertilizer application than was the vine growth.

SUMMARY

It appears that the first year's nitrogen application has shown favorable yield response in the older California vineyards growing in light sandy soils, which are deficient in crop and growth. The yield increase, on the average for all the plots, would be approximately sufficient to pay for the cost and the application of the ammonium sulfate. The quality as measured by the color, acidity, and sugar content was generally decreased rather than increased. In one instance the grower complained of excessively tight bunches with considerable bunch rot. Although the addition of phosphate and potash with the nitrogen had an unfavorable effect upon the yield increase, the general quality decrease seemed to be equivalent to that of the nitrogen alone. The berry size seemed to remain the same or possibly was increased very slightly by both treatments.

Vine shoot growth was not significantly increased by either N or NPK applications.

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Grape Regions of the United States

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PRACTICAL experience has shown that no one variety of grape is equally well suited to all sections of the country. The Concord, Delaware, and Niagara varieties, which are among the more adaptable, are not sufficiently hardy for the more northern and western regions having short growing seasons and very low winter temperatures; and in the more southern parts of the country and in the arid and semiarid sections of the Southwest they do not thrive where some other varieties do reasonably well. What has been said of these three well known grapes applies also to many of the less widely grown of our standard varieties. While the use of suitable rootstocks has helped to some extent in overcoming these handicaps from a cultural standpoint, these grapes cannot compete with varieties derived in considerable part from indigenous species that are of poorer table quality but better adapted to the environment.

Advice is constantly being sought by prospective growers about the varieties of grapes best suited to their particular localities. In order that information might be brought up to date and reliable suggestions given, an endeavor was made to learn just what had been the experience of horticultural workers throughout the country with the different varieties. The wholehearted cooperation of those men who generously gave the results of their observations and experience in this matter is hereby gratefully acknowledged. These reports have not only furnished the desired information on varietal adaptation but have also made possible some analysis of the underlying factors determining varietal behavior. From this study has emerged the regional grape map presented here (Fig. 1).

The most important single factor determining varietal behavior of grapes appears to be the length of the season free from killing frosts. The boundaries of the different regions shown on the map were largely, though not entirely, determined from the data on such length of growing season presented in the Atlas of American Agriculture (1) after checking against the reported experience of the horticultural workers mentioned above.

Atmospheric humidity during the growing season, which has so much to do with the prevalence of fungus diseases, is perhaps the next most important factor. Some varietal groups are particularly susceptible to fungus diseases and may not be grown successfully where the atmospheric humidity during the growing season is high, even though the length of the growing season is favorable. Other groups less susceptible to fungus diseases thrive best where high humidities prevail. Regions having low atmospheric humidity, but with water available for irrigation, are particularly favorable for some varieties.

Generally speaking, in those parts of the country having less than 20 inches of normal annual preciptation, fungus diseases attacking the foliage of grapes are not a serious menace to grape growing, and

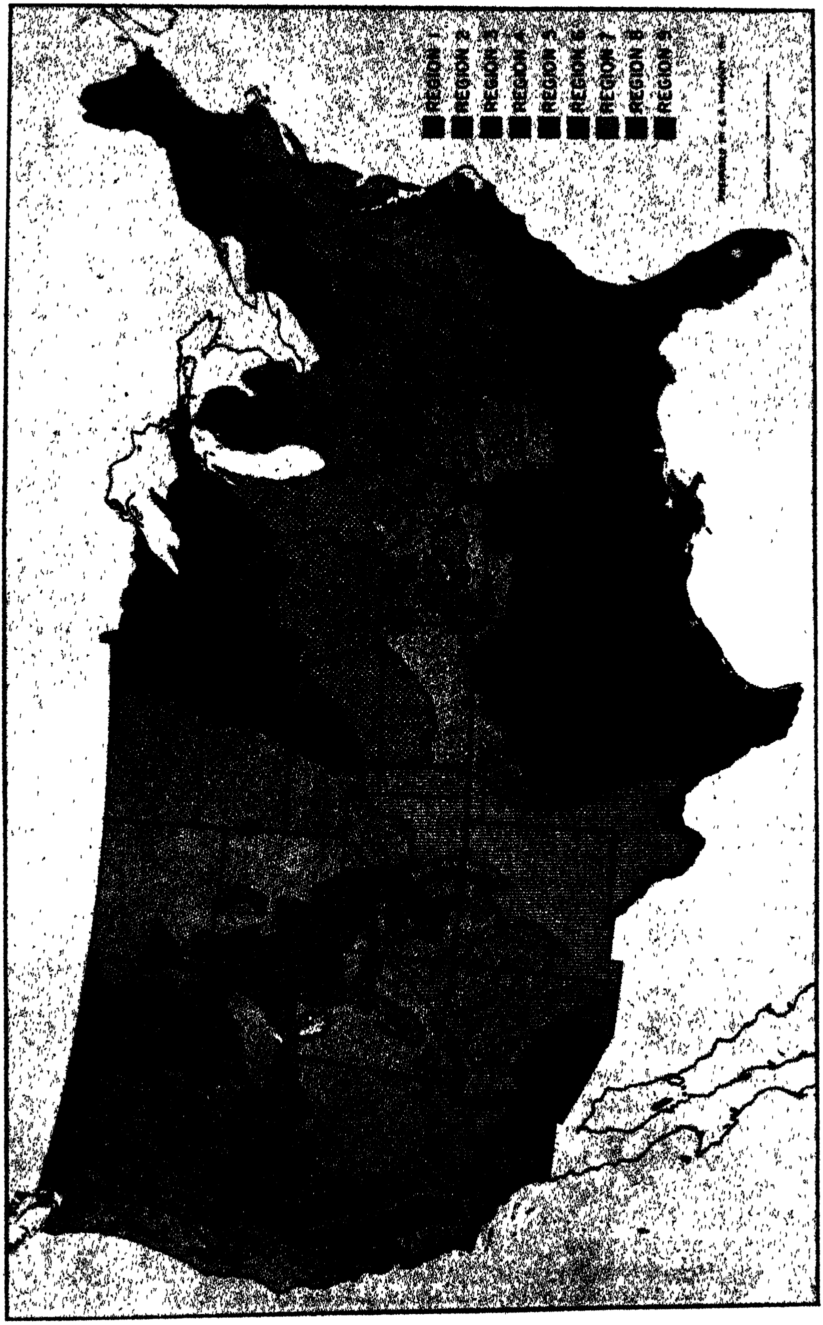

FIG. 1. Showing regions where specific varietal groups of grapes are adapted.

so in preparing the map the 20-inch rainfall limit has been arbitrarily taken as the dividing line between the eastern and western grape regions. This extends from eastern North Dakota in a slightly southwestward general direction to western Texas, and bends eastward again near the Rio Grande.

The general level of prevailing temperatures; the physical and chemical character of the soil and its exposure; the proximity of large bodies of water, which, in addition to their effect on prevailing temperatures, exert some influence on grape behavior; the more or less obscure influence of latitude, probably referable to photoperiodism; the prevalence of root parasites; individual winter dormancy requirement; and possibly other factors all enter into the matter of varietal adaptation. Obviously, a regional map can be only approximately accurate, for the reason that restricted areas within any region may have either less or more favorable conditions for grape production than prevail for the region as a whole, and on a map of limited size it is not possible to represent such exceptional areas. Furthermore, a variety may not thrive in all areas within a region. The character of the soil, the availability of necessary nutrient substances, possible excesses of harmful soil constituents, natural drainage, direction of exposure with respect to sun and prevailing winds, and other factors must all be taken into consideration. So far as it has been feasible to check this map with field observations to date, it appears to be reasonably accurate, much more so than any comparable maps to which access has been had.

Space does not permit detailed consideration of the areas included within the different regions or mention of all specific varieties that have been found adapted to them. A brief characterization of each region and mere mention of the type of grapes suited to it must suffice, and reference must be made to the map itself for more detail regarding the location of boundaries.

Region No.1:—Growing season 90 to 150 days. January mean minimum temperature —10 degrees to 15 degrees F. Average annual rainfall 25 to 45 inches for most of the region; as low as 20 or as high as 50 inches in some parts. Atmospheric humidity relatively high. Only exceptionally hardy or early ripening varieties, such as Beta and Clinton, adapted. Winter protection may be advantageous.

Region No. 2:—Growing season 150 to 180 days. January mean minimum temperature 15 degrees to 30 degrees F. Average annual rainfall 30 to 40 inches for most of the region; as low as 20 and as high as 50 inches in some parts. Atmospheric humidity relatively high. Within this region standard northern varieties, such as Concord, Niagara and Delaware, are best adapted and show their best performance.

Region No. 3:—Growing season 180 to 200 days. January mean minimum temperature 20 degrees to 35 degrees F. Average annual rainfall 35 to 50 inches for most of the region; as low as 20 or as high as 55 inches in some parts. Atmospheric humidity relatively high. This may be considered as an intermediate or transition zone where both standard northern varieties, as those mentioned above, and standard southern varieties, such as Extra, Beacon, and Carman may be grown, but within which neither kinds show their best performance.

Region No. 4:—Growing season 200 to more than 240 days. January mean minimum temperature 30 degrees to 50 degrees F. High summer temperatures and high atmospheric humidities prevail. Average annual rainfall 45 to 60 inches for most of the region; as low as 20 inches in some parts. Standard southern varieties, such as Extra and Beacon, and muscadine varieties, such as Thomas, Hunt and Scuppernong, are best adapted to most of this region. The southern parts of the Florida peninsula and the Mississippi river delta, and a narrow strip of the east coast of Texas, where killing frosts do not occur every year are not well adapted to the growing of standard bunch grape varieties. The broken lines on the map indicate the upper boundaries of these areas.

Region No. 5:—Growing season less than 90 days. January mean minimum temperature —10 degrees to 15 degrees F. Average annual rainfall 10 to 40 inches. Humidity variable. A mountainous region in general, not suitable for the growing of grapes. Exceptionally hardy varieties, represented by Beta, may perhaps be grown in selected locations.

Region No. 6:—Growing season 90 to 150 days. January mean minimum temperature —10 degrees to 25 degrees F. Average annual rainfall 5 to 20 inches. Low relative humidity. This is really a western extension of Region No. 1, but is separated from it because irrigation is required if grapes are to be grown. Only especially hardy or early-maturing northern varieties, such as mentioned above, are adapted.

Region No. 7:—This region is made up of a large irregular southwestern area and scattered isolated smaller western and northwestern areas with common characteristics as to growing season, need of irrigation, and other factors. Growing season 150 to 200 days in the northern parts to 240 days in the southern. January mean minimum temperature 20 degrees to 45 degrees F. Average annual rainfall 5 to 20 inches. Atmospheric humidity relatively low. Irrigation necessary or desirable. Standard northern varieties, including those mentioned above and many others, adapted to the northern parts and standard southern varieties, including Extra and Beacon, and selected northern varieties showing particular resistance to drought, such as Catawba, Caco and Goethe, are adapted to the southern parts. Early-maturing vinifera varieties may be grown in selected locations with winter protection. Among these may be mentioned Black Hamburg, Malaga and Sultanina.

Region No. 8:—This region, which is very long, narrow and irregular in outline, is made up largely of the valleys of the Pacific Northwest and the foothill areas of California. Growing season 150 to 240 days. January mean minimum temperature 25 degrees to 40 degrees F. Average annual rainfall 15 to 20 inches in the southern part to 60 to 100 inches in the northern. Relatively low atmospheric humidity in the southern part to relatively high in the northern areas. Selected northern grape varieties, such as Concord, Campbell Early, Niagara, and others, are adapted. Early-maturing vinifera grapes, such as Flame Tokay and Muscat Hamburg, may be grown in special locations, with winter protection advisable where the lower winter temperatures are encountered.

Region No. 9:—This region includes the hot central valley and coast sections of California, much of southern Arizona, and a narrow area bordering the Rio Grande in Texas. Growing season 200 to more than 300 days. January mean minimum temperature 40 degrees to 50 degrees F. Very high summer temperatures and relatively low humidity. Average annual rainfall 5 to 20 inches in the southern part, to an extreme of 50 inches in some northern areas. This is mainly a vinifera grape region and scores of table, raisin, and wine varieties are available, all of which thrive well. Some eastern varieties, such as Concord, Pierce, and Isabella, may be grown in the cooler locations.

While an endeavor has been made to make this map as accurate as possible, it may be that errors have occurred in its preparation. In order, therefore, that any needed modifications may be made, comments on and criticisms of it will be heartily welcome.

With these grape regions in mind, it may now be of interest to examine another map (Fig. 2) showing the principal grape-producing areas of the country. This is based on the data from the 1939 census, given by counties. Each dot represents 50,000 pounds.

This map, while showing where the larger centers of production are located does not present a full picture of the grape-growing regions. According to the 1939 census figures (2) out of the 3071 counties making up the 48 states, no less than 2782 of them, distributed through every State of the Union, produced reportable quantities of grapes, ranging from 100 pounds or less, in a few instances, to more than three-quarters of a million tons, in the case of one California county (Fresno).

Approximately 90 per cent of the grapes grown in the country are produced in California, and within that State the bulk of the tonnage is grown within the area indicated on the map (Fig. 1) as Region No. 9. These are primarily of the vinifera type.

The next most important centers of production are the counties of New York, Pennsylvania, Ohio and Michigan that border Lakes Michigan, Erie, and Ontario, the Finger Lakes section of New York, and the Hudson Valley. These and other important grape areas within these States lie principally within Region No. 2 and are given over to the production of the standard northern varieties, of which Concord is the chief representative.

In addition, it is to be noted that across Indiana, Illinois and Iowa, into eastern Nebraska and Kansas, down through Missouri and into northern Arkansas, the principal production areas are largely within Region No. 2, though part of this territory lies within Region No. 3. The standard northern varieties make up the bulk of this production, but in the Ozark section, particularly, some of the standard southern varieties do well. From southern New England down through New Jersey, Delaware, and eastern Pennsylvania, following and flanking the Appalachians to northern Alabama and Georgia (territory lying

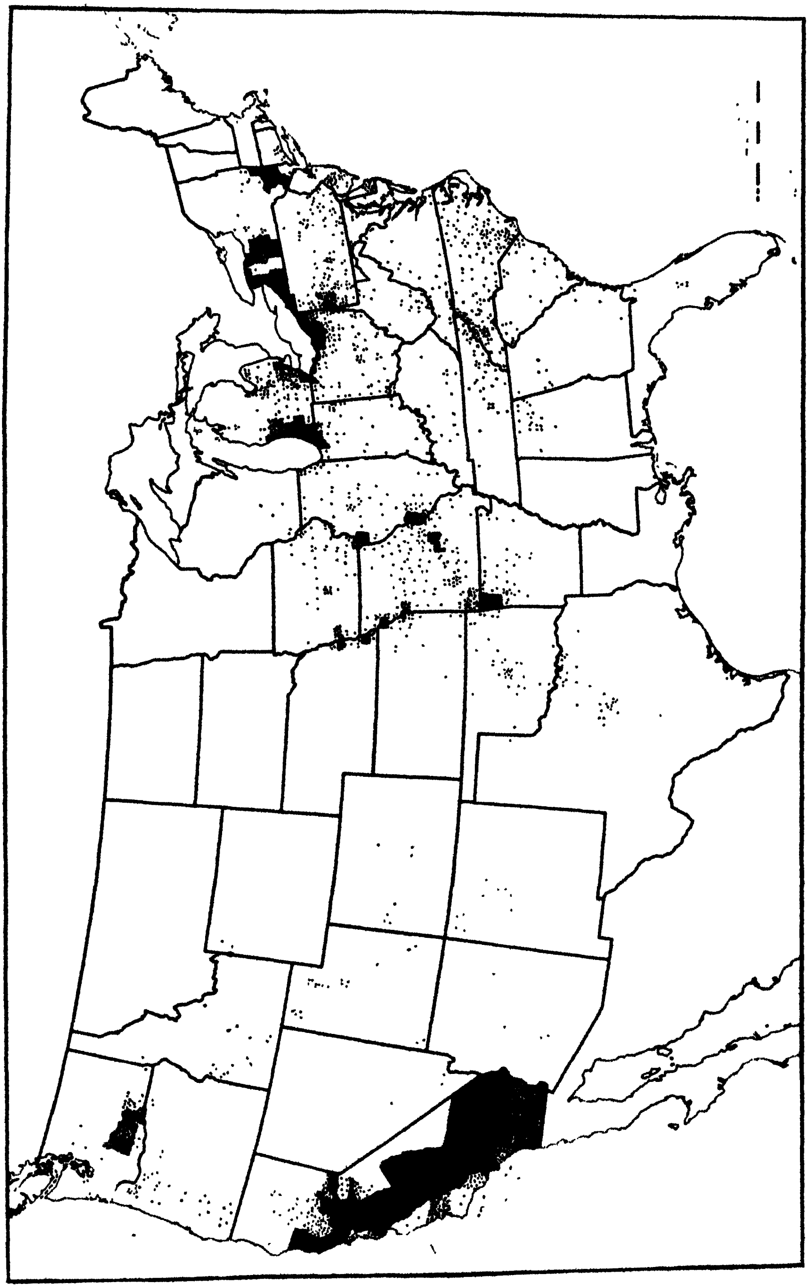

FIG. 2. Map of the United States showing the principal grape producing centers. Data for this map were taken from the Census figures for 1939, as given for individual counties within each State. Each dot represents 50,000 pounds of fruit.

within Regions Nos. 2 and 3), considerable quantities of the standard northern varieties are grown.

The Coastal Plain sections of Virginia, North and South Carolina, and Georgia, where considerable production is indicated, lie within Region No. 4, and here the muscadine grapes are of primary importance. Extensive areas in the South Atlantic and Gulf States lying within Region No. 4 show no important production centers, but selected southern bunch grapes and muscadine varieties are widely grown on a farm home basis. In Florida commercial grape growing centers are shown. Here, in addition to a few selected southern varieties, one or two of the northern grapes, particularly the Niagara, are grown on special rootstocks. The principal grape areas of Oklahoma and Texas, except the narrow strip bordering the Rio Grande, are also included in Region No. 4, and here selected standard southern varieties are of most importance.

Attention is called briefly to the scattered grape-growing centers in New Mexico, Arizona, Colorado, Utah, Nevada, and Idaho, where, as reference to the regional map will show, restricted areas exist that, by reason of favorable climatic conditions and water for irrigation, are suitable for grape culture. Attention is also called to the valleys of the Columbia, Snake, and Yakima rivers in southern and central Washington, where a rapidly expanding grape industry is now developing. Favorable length of growing season, good soil, low atmospheric humidity, and abundant water for irrigation make this area, which is part of Region No. 7, particularly suited for the growing of standard northern varieties.

Correlation of the production centers of Washington and Oregon west of the Cascade mountains with the northern part of Region No. 8 is apparent.

Finally, there remains to be mentioned that great expanse of northern territory extending from New England to the Rockies, corresponding to our Regions Nos. 1 and 6, which on the production map show no evidence of a commercial grape industry. Grapes are grown over much of this area, but primarily on a farm home basis, as those varieties hardy enough to withstand the rigors of the northern winters are too highly acid for extensive use.

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Cold Resistance of Strawberry Plants in the Early Stages of Growth[1]

By W. G. BRIERLEY and R. H. LANDON, *University of Minnesota, St. Paul, Minn.*

OBSERVATIONS at University Farm of the behavior of established strawberry plants at the beginning of growth in the spring have indicated that such plants often escape serious injury when exposed to rather severe freezes. In the early spring of 1938 plants of the Beaver and Dunlap varieties that had not been mulched during the winter had begun to grow in late March and showed several fairly well unfolded new leaves per plant. On the night of March 31 a sudden drop in temperature exposed these plants to a minimum air temperature of 19 degrees F. In the open fields and beneath these unprotected plants the ground was frozen hard although its temperature probably was somewhat higher than that of the air. These plants continued their growth with the return of warmer weather and did not appear to be injured.

A similar but more severe test occurred in the spring of 1939. Plants of the same varieties, not protected by mulch, had started to unfold their new leaves in early April, although they were not quite so far advanced as those observed during the previous spring. Frosts of varying severity occurred on nearly every night from April 1 to the 18. The plants were partially protected by light snow on April 7, 8, 11, 17, and 18, but there was no such protection on April 6 and 12 when the minimum air temperatures were 20 and 16 degrees F respectively. The temperature of the crowns at the soil surface probably was somewhat above these figures. Survival, with subsequent production of good yields under these severe conditions at the beginning of growth was 90 per cent for Dunlap and 95 per cent for Beaver.

The resistance of these growing plants to fairly low temperatures indicates that either the cold resistance acquired in the fall had been retained or that if hardiness had been lost the plants were able to regain it rapidly enough to escape serious injury. It is of interest in this connection to note the conclusions reached by Dexter (1) in his studies of hardening and cold resistance to the effect that any tendency toward growth in a plant is distinctly unfavorable for hardening or for the retention of hardiness.

In order to obtain further information relative to the cold resistance of strawberry plants under controlled conditions in the early stages of growth a study was carried on with eight varieties during early April in 1941. The varieties used were those listed in Table I. All the plants used had been potted and plunged in peat in the fall, matured, hardened, and mulched before the onset of severe cold weather. The mulch was removed on April 1. During the two weeks preceding the freezing test there was no frost and conditions were

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TABLE I—COLD RESISTANCE OF STRAWBERRY VARIETIES IN THE EARLY STAGES OF GROWTH (BASED ON GROWTH RESPONSE FOLLOWING EXPOSURE FOR 24 HOURS TO CONTROLLED FREEZING TEMPERATURES — 10 POTS PER LOT. RECORDS TAKEN TWO WEEKS AFTER PLANTS WERE RETURNED TO THE FRAMES*)

Variety	At 27 Degrees F			At 21 Degrees F		
	Vigorous	Weak	Dead	Vigorous	Weak	Dead
Beaver	10	0	0	0	3	7
Catskill	9	1	0	0	1	9
Dunlap	10	0	0	1	3	6
Premier	10	0	0	4	4	2
Minn. No. 1192	10	0	0	1	3	6
Gem	9	1	0	0	0	10
Wayzata	8	2	0	5	5	0
Minn. No. 1167	8	2	0	7	2	1

*Comparable lots of all these varieties were completely killed by exposures for 24 hours to temperatures of 16 and 10 degrees F.

favorable for growth. During the first week the minimum air temperatures generally were between 35 and 45 degrees F, and the maximum temperatures ranged between 42 and 65 degrees F. During the second week warmer weather prevailed. The lowest temperature recorded during this week was 40 degrees F on the morning of April 9; and on April 12, 13, and 14 the maximum temperatures were 79, 76, and 75 degrees F respectively. Under such conditions the plants grew rapidly, and all had two or three fully unfolded new leaves when the freezing test was begun.

On April 15, samples of 10 pots each from each of the eight varieties were taken directly to the low temperature laboratory and exposed for 24 hours to a temperature of 27 degrees F. On April 16, 17, and 18 similar samples of the growing plants were exposed directly to controlled temperatures of 21, 16 and 10 degrees F respectively for 24 hours. All samples were thawed slowly and then returned to the open frames where their growth response was observed.

The results obtained following the exposures to 27 and 21 degrees F are shown in the table. As all plants in all varieties were killed at 16 and 10 degrees F these results are not shown in the table. This table shows that in all eight varieties no plants were killed at 27 degrees F, and only a few were injured and weakened. Growth following exposure to 21 degrees F was very erratic in the eight varieties, but it is of interest to note that 18 of the 80 plants or 22.5 per cent, were able to survive and grow vigorously after this sudden and severe treatment. As there was severe injury to the Beaver, Dunlap, and Minnesota No. 1192 plants at 21 degrees F it does not appear that these varieties, generally rated as among the hardiest of local varieties, had retained the degree of hardiness usually found in dormant plants. This conclusion is given added support by the fact that all plants of all varieties were killed at 16 and 10 degrees F. As hardened dormant plants of these varieties, used in other studies, generally have escaped serious injury at 21 degrees F and often have survived fairly well at 16 or even at 10 degrees F, it is apparent that these plants in the early stages of growth were much less hardy.

The observed ability of unprotected plants in the field to withstand freezing temperatures during the early stages of growth, and the survival following exposure to controlled temperatures at 27 and 21 degrees F, as shown in the table is believed to be more likely an indication of the ability of strawberry plants to reharden rapidly to a limited degree at this stage of growth rather than that any material degree of the winter hardened condition is retained.

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Strawberry Breeding and the Inheritance of Certain Characteristics

By J. P. OVERCASH and L. A. FISTER,[1] *West Tennessee Experiment Station, Jackson, Tenn.*, and BROOKS D. DRAIN, *Agricultural Experiment Station, Knoxville, Tenn.*

STRAWBERRY breeding and inheritance studies were begun at the Tennessee Agricultural Experiment Station at Knoxville in 1928. This work was transferred to the West Tennessee Experiment Station, at Jackson, in 1935. A large number of intervarietal crosses were made and in 1937, Drain and Fister (4) reported on the progress of these strawberry breeding and inheritance studies.

Regarding the use of their fruits, three general classes of strawberry varieties are: the shipping, the freezing, and the home garden type. Each class requires certain characteristics and it is seldom in any one region that all the most desirable characteristics of the three types are found in any one variety.

Since 1938 three varieties have been introduced by the Tennessee Experiment Station, namely, Tennessee Supreme (6), Tennessee Shipper (5), and Tennessee Beauty (7). Tennessee Supreme which was introduced in 1940 is a good quality berry, especially adapted for freezing and home use, but not for shipping. Tennessee Shipper, introduced in 1941 is very firm, stands up well in transit, and holds up in size toward the end of the season better than Blakemore, which is the foremost shipping variety in Tennessee. Tennessee Beauty which was introduced in 1942 is a late-ripening variety with very attractive berries. It shows promise as a shipping and general purpose variety. These three new varieties show considerable improvement over varieties commonly grown in Tennessee at the present time.

Records of the progeny of a strawberry cross give a picture of the characteristics transmitted by the parental varieties to the offspring, provided a sufficient number of seedlings are grown. Inheritance studies help to locate varieties that transmit desirable characteristics, such as plant making ability, dense leaf area, dark green foliage color, length of petioles and disease resistance. Earliness of ripening, firmness, shape, color, texture, and flavor, and other factors affecting fruit quality when located in certain parents may be combined into new varieties by the plant breeder. In 1931 Slate (10) reported on the best parents which he had used in breeding strawberries for New York State. The progress of strawberry breeding by the United States Department of Agriculture in Maryland, Oregon, and North Carolina was reported by Darrow, Waldo, Schuster, and Pickett (2) in 1934. A survey of valuable characteristics available for strawberry breeding was given in the Yearbook for the United States Department of Agriculture for 1937 (1). Drain and Fister (4) in 1937 and Morrow and Darrow (8) in 1941 presented results of inheritance studies in strawberry breeding. Mortensen and Yarnell (9) in 1937 summarized their results in breeding strawberries for Texas, and mentioned a number of inheritance relationships which they had observed. These studies from various regions of the United States do not always give an accurate picture of how certain varieties will perform as parents when the progeny are grown in another region.

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[1] Resigned October 1, 1942.

METHODS

Pollinations were made in the greenhouse at Jackson, Tennessee in the winter; and the resulting seed stored until the following fall. The seedlings were grown in the greenhouse where they remained until they were set in the field in early spring. The seedlings were spaced 4 feet apart and the fields cultivated in both directions to prevent the runner plants from mixing. All plants produced by a hill were permitted to grow. The following spring, plant and fruit characteristics of each clon were recorded and selections for further trial were made. Seedlings not selected for further trial were discarded after the first season's fruiting. The selections were transplanted for row tests the following spring.

TABLE I—PARENTAGE OF TENNESSEE STRAWBERRY VARIETIES AND SELECTIONS REFERRED TO IN THE TEXT AND IN TABLES II AND III

Variety or Tennessee Selection	Parent		Variety or Tennessee Selection	Parent	
	Female	Male		Female	Male
Tennessee Supreme	Missionary	Premier	205	Missionary	Premier
Tennessee Shipper	Missionary	Blakemore	230	Missionary	Premier
Tennessee Beauty	Missionary	Premier	247	Missionary	Premier
12	Klondike	Aroma	289	Howard Supreme	Blakemore
26	Aroma	Klondike	294	Howard Supreme	Blakemore
50	Klondike	Aroma	357	Missionary	Fairfax
53	Klondike	Aroma	372	Dorsett	Klondike
78	Klondike	Aroma	384	Missionary	Selfed
86	Klondike	Aroma	388	Fairfax	Selfed
168	Missionary	Blakemore	McClintock	Aroma	Selfed

The parents used in the crosses reported in this paper were obtained largely from commercial sources, except the Tennessee selections. These selections are the best seedlings from earlier crosses and their parentage is shown in Table I. The British Sovereign is the most commonly grown variety in British Columbia (11) and plants of this variety were obtained from Broder Canning Company, British Columbia, Canada.

PLANT CHARACTERISTICS

The inheritance of plant characteristics is indicated in Table II. Some characteristics of the seedlings worthy of noting are that progeny from crosses with Fairfax as one parent were good plant makers. Fairfax does not make many plants, therefore it appears probable that this characteristic in the offspring is due to the influence of the other parents. A large percentage of the progeny from Fairfax crosses had dark green leaves and stout petioles. The crosses involving either McClintock or British Sovereign generally gave seedlings with no strongly marked characteristics. They were medium plant producers and the plants were medium in vigor, size, and leaf color. Seedlings with Tennessee 230 as one parent were good plant makers and had light-colored foliage. Tennessee 384 and Tennessee 388 are relatively weak F_1 selfed seedlings of Missionary and Fairfax, respectively. Progeny of a cross between these two weak seedlings were exceptionally strong plant producers. Their leaf area was dense, that is there were many leaves per plant in the hill, and the vigor was good. A large percentage of the progeny had light-green leaves and slender petioles. Disease resistance was very noticeable in these seedlings.

FRUIT CHARACTERISTICS

In Table III is given the inheritance of fruit characteristics for crosses between standard varieties and Tennessee selections. Tennessee 230 transmits earliness of ripening to many of its offspring. The highest percentages of large-sized fruits obtained during this study were from the following crosses: Tennessee 205 x Tennessee 50, Tennessee 12 x British Sovereign, Tennessee 230 x McClintock, Tennessee 357 x Fairfax, and Tennessee 247 x Tennessee 230. Tennessee 230 has a long conic berry, and many of its offspring have

TABLE II—PLANT CHARACTERISTICS OF THE PROGENY FROM SEVERAL CROSSES BETWEEN STRAWBERRY VARIETIES AND TENNESSEE SELECTIONS

Cross	Tenn. 230 X McClintock	Tenn. 53 X McClintock	Tenn. 168 X McClintock	McClintock X British Sovereign	Tenn. 12 X British Sovereign	Tenn. 294 X British Sovereign	British Sovereign X Tenn. 53	Tenn. Supreme X Fairfax	Tenn. 357 X Fairfax	Fairfax X Tenn. 372
Year notes taken	1940	1940	1940	1940	1940	1940	1940	1942	1942	1942
Number of seedlings	249	75	68	288	506	224	276	141	121	57
Plant-Making										
Good	11*	23	21	29	27	25	38	29	36	47
Medium	52	29	43	47	53	38	35	49	38	32
Poor	37	48	36	24	20	37	27	22	26	21
Leaf Area										
Dense	15	19	24	23	26	20	22	30	39	35
Medium	47	35	46	53	47	43	43	57	51	48
Poor	38	46	30	24	27	37	35	13	10	17
Vigor										
Good	26	20	25	36	36	22	24	25	34	21
Medium	46	24	40	52	41	61	40	60	44	48
Poor	28	56	35	12	23	17	36	15	22	31
Leaf Size										
Large	6	8	10	19	17	11	5	11	8	12
Medium	67	33	58	72	53	84	59	56	67	41
Small	27	59	32	9	30	5	36	33	25	47
Leaf Color										
Dark	2	20	7	26	9	24	13	33	45	47
Medium	74	56	68	63	73	71	64	61	52	31
Light	24	24	25	11	18	5	23	6	3	22
Leaf Petiole										
Long	15	6	22	29	21	12	13	21	9	8
Medium	57	47	65	71	60	88	69	52	59	48
Short	28	47	13	0	19	0	18	27	32	44
Stout	3	9	7	1	10	0	5	38	36	39
Medium	66	40	64	72	53	89	69	47	55	47
Slender	31	51	29	27	37	11	26	15	9	14

*Data for plant characteristics given as per cent of total number of seedlings observed.

TABLE II (*concluded*)

	Tenn. 247 × Tenn. 230	Tenn. 384 × Tenn. 230	Tenn. 230 × Premier	Tenn. 230 × Tenn. 78	Tenn. 384 × Tenn. 388	Tenn. 205 × Tenn. 50	Tenn. 289 × Tenn. 78	Tenn. 168 × Tenn. 86	Tenn. 168 × Tenn. 26
Year notes taken	1940	1942	1942	1940	1942	1940	1940	1940	1940
Number of seedlings	86	108	129	335	150	56	575	140	385
Plant-Making									
Good	21	54	22	24	74	15	30	34	24
Medium	43	40	48	49	16	50	51	45	45
Poor	36	6	30	27	10	35	19	21	31
Leaf Area									
Dense	34	52	25	18	60	19	26	28	27
Medium	42	43	50	38	33	46	37	40	31
Poor	24	5	25	44	7	35	37	32	42
Vigor									
Good	49	53	16	25	55	54	30	33	28
Medium	32	39	42	25	32	41	24	36	27
Poor	19	8	42	50	13	5	46	31	45
Leaf Size									
Large	17	18	5	12	21	29	10	9	8
Medium	64	66	44	47	52	71	50	46	46
Small	19	16	51	41	27	0	40	45	46
Leaf Color									
Dark	3	3	18	22	24	13	23	13	19
Medium	81	60	62	52	46	87	59	79	76
Light	16	37	20	26	30	0	18	8	5
Leaf Petiole									
Long	9	24	3	21	27	25	26	17	15
Medium	37	56	52	47	56	75	38	45	46
Short	54	20	45	32	17	0	36	38	39
Stout	18	17	25	29	15	5	24	18	26
Medium	63	57	43	39	53	90	37	37	34
Slender	19	26	32	32	32	5	39	45	40

a similar shape. Necked fruits were common among the progeny from Tennessee 230 x Premier, Tennessee 168 x Tennessee 86, Tennessee 168 x Tennessee 26, Fairfax x Tennessee 372, and Tennessee 384 x Tennessee 230. Progeny from Fairfax crosses and from Tennessee 230 x Premier had a high percentage of rough and irregular fruits. Both the external and internal color of many seedlings from Tennessee 168 x Tennessee 86 and from McClintock x British Sovereign were light. All Fairfax crosses and Tennessee 384 x Tennessee 230 gave many seedlings with dark external and internal color. Soft flesh characterized many of the seedlings from Tennessee 12 x British Sovereign, McClintock x British Sovereign, Tennessee 247 x Tennessee 230, Tennessee 230 x Premier, and Tennessee 230 x McClintock. Crosses involving Fairfax, Tennessee 384, or Tennessee 388 as one parent and the cross Tennessee 230 x Premier gave many offspring that had sweet and highly flavored fruits.

British Sovereign in Canada is reported to have medium to large, very uniform rich flavored fruits without a white core. In Tennessee it has large, soft, white-centered, poorly flavored fruit and transmits many of these characteristics to its progeny. British Sovereign proved to be a poor parent in Tennessee, and few of its seedlings were saved

TABLE III—FRUIT CHARACTERISTICS OF THE PROGENY FROM SEVERAL CROSSES BETWEEN STRAWBERRY VARIETIES AND TENNESSEE SELECTIONS

Cross	Tenn. 230 × McClintock	McClintock × Brit. Sovereign	Tenn. 12 × Brit. Sovereign	Tenn. Supr. × Fairfax	Tenn. 357 × Fairfax	Fairfax × Tenn. 372	Tenn. 247 × Tenn. 230	Tenn. 384 × Tenn. 230	Tenn. 230 × Premier	Tenn. 230 × Tenn. 78	Tenn. 384 × Tenn. 388	Tenn. 205 × Tenn. 50	Tenn. 168 × Tenn. 86	Tenn. 168 × Tenn. 26
Year notes taken	1940	1940	1940	1942	1942	1942	1940	1942	1942	1940	1942	1940	1940	1940
Number of seedlings	249	288	506	141	121	57	86	108	129	335	150	56	140	385
Season														
Early	*	*	*	3†	5	18	*	84	39	*	31	*	*	*
Medium	*	*	*	91	75	72	*	15	57	*	62	*	*	*
Late	*	*	*	6	20	10	*	1	4	*	7	*	*	*
Size														
Very large	0	1	3	1	2	2	2	0	0	2	0	0	2	3
Large	24	21	22	18	22	14	21	5	5	20	13	37	18	19
Medium	59	62	63	70	59	74	40	73	67	54	70	52	46	64
Small	17	16	12	11	17	10	37	22	28	24	17	11	34	14
Form														
Round	1	19	12	25	32	9	1	18	32	6	24	5	11	5
Round conic	34	77	71	75	63	84	31	82	66	41	79	61	51	69
Long conic	40	9	11	1	4	0	53	6	5	38	1	11	18	6
Wedged	33	8	19	7	11	14	30	1	0	34	4	25	26	20
Necked	8	11	3	11	21	33	29	32	45	9	19	2	34	34
Rough	28	12	38	52	64	65	5	25	54	21	37	29	13	19
Smooth	72	88	62	48	36	35	95	75	46	79	63	71	87	81
Calyx														
Large	31	13	13	47	27	18	15	21	15	19	7	34	31	36
Medium	55	62	70	49	71	66	63	76	66	58	54	53	55	58
Small	14	25	17	4	2	16	22	3	19	23	39	13	14	6
Reflexed	70	68	51	69	55	42	82	74	62	81	82	41	81	80
Constricted	30	32	49	31	45	58	18	26	38	19	18	59	19	20
Seeds														
Large	8	1	3	33	16	0	23	22	5	7	1	13	8	15
Medium	67	32	56	66	72	69	53	66	55	42	58	55	55	58
Small	25	67	41	1	12	31	24	12	40	51	41	32	37	27
Superficial	21	20	32	51	59	30	33	52	62	40	45	14	25	8
Sunken	79	80	68	49	41	70	67	48	38	60	55	86	75	92
External Color														
Light red	17	44	23	7	11	21	13	13	16	24	24	20	29	12
Medium red	65	50	60	50	63	49	71	53	61	61	57	64	62	69
Dark red	18	6	17	43	26	30	16	34	23	15	19	16	9	19
Internal Color														
Light red	21	55	33	11	29	18	27	37	34	39	39	30	43	41
Medium red	69	42	58	47	53	59	66	47	51	52	49	59	56	52
Dark red	10	3	9	42	18	23	7	16	15	9	12	11	1	7
White core	63	56	51	65	71	79	57	39	51	74	68	88	64	59
Core														
Large	14	16	26	10	16	0	14	4	1	29	3	37	12	19
Medium	48	60	58	58	52	33	50	46	28	48	36	54	44	54
Small	38	24	16	32	32	67	36	50	71	23	61	9	44	27
Hollow	84	75	86	42	55	79	90	58	66	93	78	70	66	74
Solid	16	25	14	58	45	21	10	42	34	7	22	30	34	26
Texture														
Firm	15	2	4	41	20	23	11	14	20	21	26	16	27	21
Medium	51	52	41	48	58	54	50	56	44	55	43	64	53	62
Soft	34	46	55	11	22	23	39	30	36	24	31	20	20	17
Flavor														
Sweet	12	32	18	49	50	25	12	37	36	15	23	11	9	15
Subacid	72	53	63	47	48	63	71	58	59	60	62	62	68	68
Sour	16	15	19	4	2	12	17	5	5	25	15	27	23	17
Highly flavored	2	0	1	21	11	18	0	3	20	1	11	6	3	1
Medium flavor	39	63	50	57	58	59	54	71	61	39	59	37	29	35
Poorly flavored	59	37	49	22	31	23	46	26	19	60	30	57	68	64
Remarks														
Save	17	4	4	18	13	7	17	6	7	13	18	9	11	5
Discard	83	96	96	82	87	93	83	94	93	87	82	91	89	95

*Records incomplete.

†Fruit characteristics given as per cent of total number of seedlings observed.

for further trials. McClintock showed more promise as a parent than did British Sovereign, but its offspring were poor in quality and few were saved. Fairfax transmits its dark color, good flavor and sweetness of fruit to many of its progeny, but many produce fruit which is rough and irregular in shape. Progeny of Tennessee 230 are early, but many seedlings carry the long conic shape and soft texture of this parent. The cross between Tennessee 384 and Tennessee 388 gave many progeny with vigorous plant characteristics and a high percentage of good-quality fruit. Eighteen per cent of the progeny were worthy of saving for further observation. Perhaps there is greater possibility of developing desirable varieties through the crossing of inbred lines than has yet been realized.

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The Response of Strawberries to Boron

By L. P. Latimer, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

CERTAIN apple trees growing on Charlton loam soil at the Horticultural Farm at Durham, New Hampshire have in certain years produced corky fruit. This condition was remedied by borax applications (4). It is thus known that boron deficient areas exist on this farm. This condition does not seem to be general, yet other areas may closely approach a boron deficient condition. Plants in such locations could suffer from an insufficient boron supply in summers of severe drouth (3). In fact, in just such seasons certain strawberry plants and fruits have exhibited symptoms resembling boron deficiency as illustrated by Hoagland and Snyder (1).

Hoagland and Snyder (1) reported that 0.1 parts per million of boron in the culture solution completely prevented boron deficiency symptoms in the strawberry in spring but not in summer. They observed that strawberries need more than a trace of boron for normal growth and healthy roots. Purvis and Hanna (5) list the strawberry as very sensitive to borax, indicating that no more than 5 pounds per acre can be safely applied to the strawberry bed. No mention is made of the time of year applied.

In a test of the effect of different amounts of boron on apple trees and crop (4) the writer noted that wild strawberries growing in the sod where borax was applied were very sensitive and easily injured with applications of only 2 pounds per tree.

For these reasons an experiment was set up to determine the need for and tolerance of boron by strawberries. In a preliminary test, Howard 17 strawberries were planted in the spring of 1938. In 1939 a randomized block arrangement was set up with seven replications of each treatment. Borax was applied in May 1939, just after full bloom, by broadcasting it over the plots, sweeping the chemical from the leaves to avoid direct injury to the foliage.

The data presented in Table I indicate very slight toxicity following applications of 5 pounds of borax per acre. Injury from the lighter applications was evident as a purple coloration of the leaf margins.

TABLE I—EFFECT OF BORAX APPLICATIONS ON YIELD AND BERRY SIZE OF HOWARD 17 STRAWBERRY 1939 (BORAX APPLIED AFTER FULL BLOOM 1939)

Borax Applied (Lbs Per Acre)	Average Yield 1/200 Acre Plots (Kgms)	Per Cent Control	Average Berry Size (Grams)	Amount of Scorch on Leaves
0 (Control)	24.96	100.0	8.8	None
5	24.84	99.5	9.0	None to trace
10	26.30	105.4	8.4	Slight
20	24.88	99.7	8.2	Light
40	23.37	93.6	9.2	Medium
80	18.06	72.4	9.2	Medium to severe

By analysis of variance F = 2.57 and is within the five per cent level of significance for 30 degrees of freedom.

Least difference between yield means significant at the 5 per cent level = 4.31.

Differences between means for berry size are not significant.

With 40 pounds of borax, the leaf margins were definitely burned inward for ⅛ inch. With 80 pounds of borax per acre, the margins of the leaves were scorched to a depth of ¼ inch and leaf surfaces were often spotted with purplish areas. Although leaf injury was present, the yield of fruit was definitely reduced only in the plots receiving 80 pounds of borax per acre. Berries were occasionally misshapen and "seedy" in the plots receiving either 40 or 80 pounds of borax. The fruit in plots receiving 80 pounds of borax per acre was dull dark red and of an unattractive appearance. There was no significant difference in berry size between the control and any of the borax applications or between any of the different amounts of borax.

In 1940, Howard 17 strawberries were planted in a 5 by 5 latin square. Borax was applied to the soil June 15 of the same year. The first runner plants were just appearing at this time and none had yet taken root. The borax was distributed uniformly between the plants in the row and on each side of the row, leaving 1 foot of space untreated between each row. Care was taken to prevent borax from coming in contact with the plants. The writer (2) has previously shown that in this soil strawberry plants in one row were not affected by the fertilizer treatments of adjacent rows even with heavy applications of chemicals. This was also true in the present experiment, injury being definitely confined to the rows receiving the heaviest applications of borax. By the time the runners were ready to take root the borax had been washed into the soil by the rain. The results are presented in Table II.

Observations on May 6, 1941 showed that all rows except those which had received 200 pounds of borax per acre were of normal width for a matted row. In plots that had received 200 pounds of borax per acre the rows were narrow and contained fewer runner plants than rows in plots receiving less borax.

The data in Table II indicates unfavorable results from the use of more than 25 pounds of borax per acre. Both runner plant production and yield were reduced in plots receiving either 100 or 200 pounds of borax per acre, the differences being statistically highly significant.

TABLE II—EFFECT OF BORAX APPLICATIONS ON YIELD AND RUNNER PLANT PRODUCTION OF HOWARD 17 STRAWBERRY, 1941 (BORAX APPLIED JUNE 15, 1940)

Borax Applied (Lbs Per Acre)	Average yield per 1/300 Acre Plots (Quarts)	Per Cent Control	Average Number Runner Plants Per Parent	Per Cent Control
0 (control)	25.2	100.0	33.4	100.0
25	24.0	95.2	32.6	97.6
50	21.2	84.1	30.0	89.8
100	17.2	68.2	25.8	77.2
200	10.6	42.1	19.2	57.5
F	16.79		13.94	
Degrees of freedom for 'error'	13.0		13.0	
Least difference significant at				
P = .05	4.45		4.82	
P = .01	6.24		6.75	

The striking parallel in reduction of yield and runner plant production influenced directly by the amount of borax applied is borne out by the highly significant correlation of .898 between berry yield and number of runner plants produced.

The writer concludes from the above experiments and from observations on wild strawberries that the strawberry is very sensitive to boron and that under southeastern New Hampshire conditions more than 5 pounds of this element or 25 pounds of borax per acre are injurious whether applied to the bearing or to the newly planted bed; also that no benefit was derived from 25 pounds of borax per acre compared to the control since the greatest yield and runner production occurred both in rows that received no borax and in those which received 25 pounds per acre. With the Charlton loam type of soil found on the Horticultural Farm, the strawberry seems to tolerate somewhat greater applications of borax than in Virginia as reported by Purvis and Hanna (5).

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Three-Year-Old Fruiting Canes in the Latham Raspberry[1]

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THE biennial habit of the red raspberry cane has long been recognized, although abnormalities in the manner of growth and fruiting have been observed at times. Normal growth and fruiting habits have been studied and the probable cause of decline and death investigated. In all of these studies, so far as the writer is aware, the biennial habit of the red raspberry cane has not been altered materially. However, familiarity with the performance of the red raspberry plant led the author to the belief that its biennial habit possibly could be changed by experimental treatment. Although any change so induced hardly would have practical value the study herein reported was undertaken.

Preliminary work was begun in 1935 with some Latham plants grown in half-bushel metal tubs. Three plants were disbudded, and throughout the season all new sprouts were removed as soon as they appeared above the surface of the soil. Thus fruiting was prevented and any extension of life depended wholly upon the performance of the 2-year-old canes. The foliage on these plants was darker green than that on 2-year-old canes of comparable plants not so treated. Blossom buds continued to appear on the treated plants until July 29. Toward the end of the season a few canes produced branches on the basal 12 inches. These branches, formed in what normally would have been the fruiting year for the canes, were few in number, lacked vigor, and were late in maturing in comparison to normal first-year canes.

All plants were stored in late fall to avoid exposure to severe winter conditions. The following year, when placed under conditions favorable to growth, these canes in their third season developed a few flowering laterals that were noticeably low in vigor. All canes died before any fruit was formed, but this failure possibly was hastened by the unusually high temperatures prevailing in 1936.

The study was repeated in 1937 with somewhat stronger plants. These treated plants continued to produce a few blossom buds as late as October 22. Branches that developed during what would normally have been the fruiting year were somewhat more vigorous than those of the earlier study, but they were noticeably less vigorous than new canes on untreated plants. Some branches grew at a height of 2 to 3 feet on the canes. The canes produced a moderate amount of bloom on a few scattered laterals and ripened a few berries in the third year before they died.

A continuation of the study was begun in 1940 with the tubbing of selected vigorous plants. In the spring of 1941, the canes were thinned to three or four of the strongest per plant, and were headed to about 3 feet. The plants were then divided into three lots of six plants each and treated as follows:

Lot 1. Disbudded; new canes allowed to grow.
Lot 2. Plants allowed to fruit; all sprouts removed throughout the season.
Lot 3. Disbudded, and all sprouts removed throughout the season.

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The principal effect of the treatment in Lot 1 was loss of the crop. Only a few late blossom buds were formed, and the foliage of the disbudded canes was only a little darker green than that of untreated plants. The canes of treated plants that normally would have fruited all died by the end of the 1941 season. The new canes grew 6 feet high and matured normally. Obviously, disbudding alone did not prolong the life of the canes.

In Lot 2 the plants ripened their crop at the usual time. A few canes developed weak vegetative laterals, usually near the base. Generally the treated canes in their second season were much weaker than those in the other two lots.

In Lot 3 some plants continued to develop blossom buds until September 24. The late buds were produced on short laterals that came from accessory buds which usually do not develop. Most of the canes of the treated plants developed vegetative branches by early August. Some branches came from late developing accessory buds, and some were vegetative extensions of very short laterals that up until midseason had produced a succession of blossom buds. Still other branches developed near the base of strong laterals from which all blossom buds had been removed. These latter branches did not arise from latent buds but were adventive growths from the node at which the lateral arose. These new vegetative branches varied in vigor from strong to

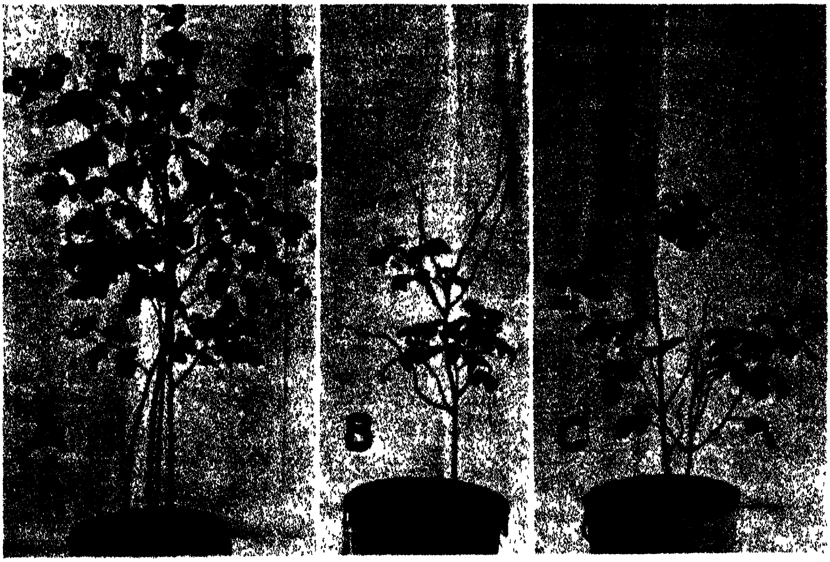

Fig. 1. Appearance of representative plants in the third year.* A, From Lot 1; disbudded in 1941, new canes allowed to grow; canes shown are second year; no canes lived into third year. B, From Lot 2; plants allowed to fruit in 1941, sprouts removed; third year growth in 1942 very weak; a few berries ripened. C, From Lot 3; disbudded in 1941, sprouts removed; third year cane showing only a few moderately vigorous fruiting laterals from two-year branches; berries of average size, few per lateral.

*All sprouts removed in 1942.

weak. Their leaves were smaller in size but comparable in color to those borne on new canes. All these branches were late in maturing and invariably the portion of the 2-year cane above the uppermost branch died by the end of the season.

After winter storage the tubbed plants were placed under conditions favorable for growth in the spring of 1942 and all sprouts were removed as they appeared. In Lot 1 there were no 3-year canes. The 2-year canes that had developed during the preceding year appeared to be normal in all respects for tub grown plants (Fig. 1, A).

In Lot 2 the plants were very weak. Only three plants were strong enough to develop a few weak flowering laterals from the 2-year branches on the 3-year canes (Fig. 1, B). These weak laterals, however, set and matured a few medium sized berries. All canes died soon after the berries ripened.

The plants in Lot 3 developed fruiting laterals of moderate vigor from the 2-year branches, but only a few were produced by an individual cane (Fig. 1, C). The berries ripened normally and were of average size, but only a few were borne on each lateral. These canes died earlier than the 2-year fruiting canes of Lot 1.

An examination of cane structure indicated that the various treatments had caused little or no increase in the normally limited development of second year xylem. In the third season little or no new xylem was formed. Although the treatments may have prolonged life of the canes into the third season, it was obvious that xylem formation was not greatly affected.

These studies show that it is possible to prolong the life of Latham raspberry canes into the third year, but this is accomplished with a material loss in both vigor and yield.

Raspberry and Blackberry Breeding: Production of Tetraploid Raspberries

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FROM a cytological viewpoint the genus Rubus is unique in that the species of the subgenus *Eubatus,* the blackberries and dewberries, exhibit a wide range of chromosome number (from the diploid 14, to the duodecaploid 84), while the species of the subgenus *Idaeobatus,* the raspberries, have with few exceptions been found to be diploid. Rosanova (6) has reported the occurrence of autotetraploid forms of *Rubus idaeus* in the mountains of Siberia. A few garden varieties of raspberry, particularly La France, Hailsham, and Colossus, have also been found to be tetraploid. Though these tetraploids are minor varieties, they are all fall-fruiting and high-flavored, and have disease-resistant foliage. The horticultural varieties of blackberries and dewberries are mostly polyploids, the percentage of varieties in each group so far as known being approximately: 2x, 20 per cent; 3x, 2 per cent; 4x, 40 per cent; 6x, 20 per cent; 7x, 2 per cent; 8x, 8 per cent; 9x, 4 per cent; and 12x, 4 per cent. However, of the total acreage cultivated, the 2x blackberries represent only 2 to 4 per cent, the 4x about 80 per cent, and the 6x from 16 to 18 per cent. The 9x varieties, Pacific and Cascade, are becoming popular in Oregon and Washington. It might be expected, therefore, that raspberries would provide favorable material for chromosome doubling by artificial means and that the resulting plants might have value in a small-fruit breeding program. The accidental occurrence of the fertile tetraploid Nessberry (7) among the highly sterile F_1 progeny (diploid) from a cross between the southern dewberry, *R. trivialis,* and the Brilliant red raspberry, *R. strigosus,* has also suggested the possibility of inducing fertility in sterile interspecific Rubus hybrids by means of polyploidy.

MATERIALS AND METHODS

To induce chromosome doubling, approximately 2,500 raspberry seedlings at the green cotyledon stage were soaked in aqueous solutions of colchicine (0.2 to 0.5 per cent) for intervals varying from 5 to 24 hours in January 1939. Most of the treated seedlings were F_1 progeny of varietal crosses of red raspberries, *Rubus idaeus* or *R. strigosus,* and the interspecific hybrids of (*R. idaeus* x *strigosus*) x *R. parvifolius* and of *R. occidentalis* x *R. idaeus.*

In the summer of 1941, all plants suspected of being partially or wholly tetraploid because of general appearance of foliage were studied with respect to pollen and calyx size, percentage of abortive pollen, leaflet shape, drupelet size, and seed weight. If the plants seemed to be partially tetraploid, data were obtained from the affected part. Eighteen plants were thus selected and the ploidy of 17 of these plants was

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TABLE I—POLLEN AND SEED MEASUREMENTS OF RASPBERRIES AND BLACKBERRIES

Variety or Cross	Number Plants	Chromosome Number* 2x	Frequency Distribution of Pollen According to Size Group (Diameter in Microns)								Mean Pollen Diameter ±S.E. (Microns)	Per Cent Aborted Pollen	Mean Weight of 100 Seed (Mg)
			23	28	33	38	43	48	53	58			
A—Untreated Commercial Varieties of Blackberries and Raspberries													
1. *Raspberries*													
Cumberland	1	14+	6	20	9	—	—	—	—	—	27.5 ±3.0	5	187
Taylor	1	14+	6	31	7	1	—	—	—	—	27.0 ±3.0	20	187
Rubus parvifolius	1	14+	2	17	21	—	—	—	—	—	29.5 ±2.5	25	231
Hailsham	1	28+	3	21	49	93	47	—	—	—	36.3 ±0.4	16	272
Colossus	1	28+	—	—	—	—	—	—	—	—	34.3 ±0.4	—	252
No. 8 (Lloyd Geo. × Ranere)	1	14–	—	—	—	—	—	—	—	—	—	—	105
Latham	1	14+	—	—	—	—	—	—	—	—	—	—	170
Ranere	1	14+	—	—	—	—	—	—	—	—	—	—	99
Lloyd George	1	14+	—	—	—	—	—	—	—	—	—	—	143
Dixie	1	14–	—	—	—	—	—	—	—	—	—	—	139†
Sodus	1	14–	—	—	—	—	—	—	—	—	—	—	162
Potomac	1	14–	—	—	—	—	—	—	—	—	—	—	215
No. 1202 (Potomac × Latham)	1	14–	—	—	—	—	—	—	—	—	—	—	165
Naples	1	14–	—	—	—	—	—	—	—	—	—	—	179
Bristol	1	14–	—	—	—	—	—	—	—	—	—	—	155
2. *Blackberries*													
Early Harvest	1	14+	34	1	—	—	—	—	—	—	22.5 ±1.5	25	117
Burbank Thornless	1	14+	11	34	—	—	—	—	—	—	26.0 ±1.5	5	—
Oregon Evergreen	1	28+	2	8	18	7	—	—	—	—	31.5 ±3.5	—	—
Lawton	1	28+	4	19	17	—	—	—	—	—	29.0 ±3.0	25	230†
Brainerd	1	28+	5	16	18	1	—	—	—	—	29.5 ±3.0	—	262†
Eldorado	1	28+	—	—	—	—	—	—	—	—	—	—	226
Boysen	1	42+	—	3	14	21	3	—	—	—	35.5 ±3.5	10	444
Logan	1	42+	—	—	—	—	—	—	—	—	—	—	255†
Austin Thornless	1	56+	—	1	12	31	1	—	—	—	35.5 ±2.5	—	—
B—Intervarietal and Interspecific Hybrid Raspberries (4n Sectors Considered Separately)													
Taylor × Rosy	1	14–	2	17	5	1	—	—	—	—	28.0 ±3.0	15	140
No. 8 Latham × Ranere	3	14–	5	50	30	1	—	—	—	—	29.0 ±2.5	22	—
(Lloyd George × Ranere) × Pynes Royal	3	14–	3	63	20	—	—	—	—	—	28.5 ±2.0	8	157
(Lloyd George × Ranere) × Pynes Royal	1	28+	—	—	—	—	—	—	—	—	—	—	249
Newburgh × 1109	2	14–	1	58	11	—	—	—	—	—	28.0 ±2.0	13	154
Newburgh × *R. parvifolius*	5	14–	14	87	40	3	4	3	1	—	29.5 ±4.5	58	—
Rubus parvifolius × Newburgh	3	14–	6	42	13	—	—	—	—	—	28.0 ±2.0	43	—
Rubus parvifolius × Pynes Royal	8	14–	8	49	14	1	1	—	—	—	28.0 ±3.0	—	—
Trailing hybrid × Taylor	9	14–	9	58	65	—	—	—	—	—	29.5 ±3.5	49	193
Taylor × *Rubus parvifolius*	16	14§	28	44	82	7	4	—	1	—	29.0 ±3.5	69	192
Taylor × *Rubus parvifolius*	9	28§	—	17	69	127	46	1	3	—	38.5 ±4.5	57	281
1202 × Taylor	6	14§	50	152	22	—	—	—	—	—	26.0 ±2.5	29	150
1202 × Taylor	4	28§	—	14	53	80	41	—	—	—	36.5 ±4.0	32	247
1202 × Taylor–36-P-8	1	28+	—	9	13	18	—	—	—	—	33.0 ±0.1	30	243
Cumberland seedling	1	28+	—	—	—	—	—	—	—	—	—	—	299
Cumberland × Imperial	12	14§	5	89	71	2	—	—	—	—	29.5 ±2.5	20	194
Cumberland × Imperial-51-P-7	1	28§	—	1	13	21	4	—	—	—	35.5 ±3.0	20	328
Taylor × Imperial													
2n sector	1	14–	—	20	16	—	—	—	—	—	32.0 ±2.0	20	137
4n sector	1	28+	—	—	5	25	5	—	—	—	37.5 ±2.5	30	171
Latham × Red Cross	2	14§	2	35	11	2	—	—	—	—	29.0 ±2.5	35	133
Latham × Red Cross	1	28+	—	6	16	8	1	—	—	—	32.5 ±3.5	35	183

TABLE I—*Concluded*

Variety or Cross	Number Plants	Chromosome Number* 2x	Frequency Distribution of Pollen According to Size Group (Diameter in Microns)								Mean Pollen Diameter ±S.E. (Microns)	Per Cent Aborted Pollen	Mean Weight of 100 Seed (Mg)
			23	28	33	38	43	48	53	58			
C—Interspecific Hybrids of Blackberries and of Blackberries and Raspberries													
Logan (6x) × Oregon No. 62 (Lloyd George selfed (2x)	12	28–	7	42	87	46	12	1	—	—	33.0 ±4.5	80	—
Logan × Oregon 189 (Cuthbert × Lloyd George)	22	28–	17	72	132	52	12	2	3	—	32.0 ±5.0	80	—
Logan × Jumbo (4x)	6	35–	—	19	39	19	2	—	—	—	32.5 ±3.5	45	—
Logan × Oregon Evergreen (4x)	9	35–	1	12	67	49	3	4	—	1	34.5 ±4.5	34	—
Agate Beach (6x) × Taylor	1	28–	—	3	2	1	2	3	1	—	38.5 ±8.5	95	—
Branstetter × Taylor	1	35–	—	3	5	1	4	3	1	1	38.5 ±8.0	95	—
Oregon 606 (10x)‡ × Lawton (4x)	7	49 -	3	23	46	23	1	—	—	—	32.5 ±4.0	54	—
Eldorado (4x) × Boysen (6x)	12	35–	-	33	110	41	2	1	1	—	32.5 ±3.5	28	410
Boysen (6x) × Austin Thornless (8x)	19	49–	—	7	41	136	62	13	1	2	38.0 ±4.5	48	—

*Known or expected chromosome number: known +, expected –, counts of selected plants §.
†After Darrow and Sherwood (1931) (3).
‡Oregon No. 606 = Zelinski (12x) × Austin Thornless (8x).

later verified by chromosome counts. Several known diploid seedlings of each cross were used for comparison.

The chromosome counts were made from acetocarmine smears of shoot apexes and, when possible, from root material (rooted shoot-tips). When available, several shoot apexes from different branches were studied. Where the tissues were mixoploid it was not possible always to determine with certainty the type of chimera. However, by focussing carefully, a periclinal chimeric condition of some of the meristems could be determined by actual chromosome counts.

Pollen samples from both treated and untreated plants of several interspecific hybrids were also examined to obtain the percentage of unreduced pollen grains. This was done in the hope of isolating partially fertile F_1 interspecific hybrids to be used later in obtaining fertile amphidiploid plants.

COMPARISON OF DIPLOID AND TETRAPLOID PLANTS

A comparison of pollen grain and seed size of different species and varieties of raspberries and blackberries (Tables I-A and II) indicates that varieties having the same chromosome number are remarkably similar in both pollen and seed size (see also diploids in Table I-B). Taylor red and Cumberland black raspberries averaged 187 milligrams per 100 seeds, while Hailsham and Colossus, respectively, averaged 272 and 252 milligrams per 100 seeds. In both diploid and tetraploid blackberry varieties a positive relationship between both pollen grain and seed size and chromosome number may also be seen. The hexaploid Boysen trailing blackberry had larger pollen and seed than the tetraploid blackberries. However, the Logan (6x) seed was not larger than that of the blackberry tetraploids nor was pollen of Austin Thornless (8x) larger than that of Boysen (6x). In the few varieties studied, the pollen grains of the diploid blackberries were smaller and more uniform than those of the diploid raspberries. Both pollen and seed size of diploid raspberries and blackberries clearly indicate their ploidy.

In Tables I-B and II the data for treated raspberry plants that were selected as tetraploids on the basis of pollen and seed size are given along with similar data for diploid plants of the same parentage. The pollen and seed size of the selected tetraploids was consistently larger than that of the diploids with which they were compared. In general, pollen and seed size of these selected tetraploids was comparable to that of the tetraploid varieties Hailsham and Colossus.

TABLE II—SUMMARY TABLE — RANGE OF MEASUREMENTS IN DIFFERENT POLYPLOID GROUPS OF RASPBERRIES AND BLACKBERRIES

Type	X Number	Number Crosses or Varieties	Mean Pollen Diameter	Per Cent Aborted Pollen	Mean Weight 100 Seed (Mg)
Raspberry . . .	2	13	27.0-29.5	5-25	99-231
	4	2	34.3-36.3	16-	252-272
Blackberry.	2	2	22.5-26.0	——	117-
	4	4	29.0-31.5	——	226-262
	6	2	35.5-	——	255-444
	8	1	35.5-	——	——
Raspberry crosses and hybrids	2	13	26.0-32.0	20-69	133-194
	4	8	32.5-38.5	20-57	171-328
Blackberry and blackberry-raspberry hybrids	4	3	32.0-38.5	80-95	——
	5	4	32.5-38.5	28-95	410-
	7	2	32.5-38.0	48-54	——

A study of representative shoot apexes from 17 selected seedling plants showed that two shoots were entirely tetraploid, four had tetraploid sectors, and three seemed to be periclinal chimeras, having a diploid epidermis and a tetraploid core. In the remaining eight plants, the shoot meristem material examined did not possess tetraploid tissue. However, other sectors of these plants appeared to be tetraploid, as indicated by chromosome counts made in root tips, by pollen and seed size, and by general appearance of the sector.

In Table I-B a comparison is given of pollen of a plant entirely tetraploid, 36–P–8, and for all four plants wholly or partly tetraploid of the same parentage, 1202 (purple x red raspberry) x Taylor. The two sets of data are not significantly different. Figs. 1-A and B show the tetraploid 36–P–8 and a diploid plant of the same cross. In the table, data for both the diploid and the tetraploid sectors of a plant of the cross Taylor x Imperial are also compared. In this seedling, size of both pollen and seed from the tetraploid sector is considerably larger than that from the diploid part.

INTERSPECIFIC HYBRIDS

The variability in pollen grain diameter, as indicated by their range (Tables I and II), was least in the varieties and intervarietal crosses and greatest in the progeny of interspecific crosses in which the parents

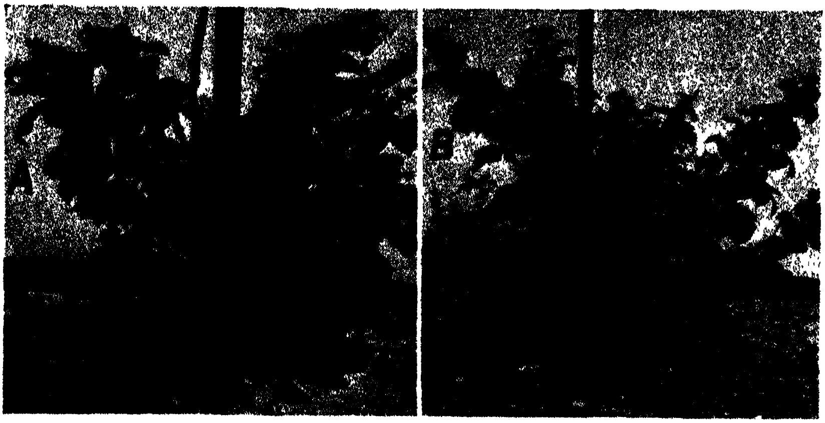

FIG. 1. A, Tetraploid plant 36–P–8 (1202 (= Potomac x Latham) x Taylor). Note large, wrinkled leaves in contrast to the smoother ones in B. B, diploid plant from the same cross, 1202 x Taylor.

had different chromosome numbers.

Very large pollen grains, presumably having the unreduced chromosome number, appeared to be most frequent in the hybrid populations having high percentages of abortive pollen and a wide range of pollen size. It is probable that unreduced gametes are a result of complete failure of chromosome pairing in the pollen mother cells, followed by the formation of dyads.

POLLEN STERILITY

In the raspberry crosses (Tables I-B and II) the percentage of abortive pollen was as high as 69 per cent for diploids of the cross Taylor x *Rubus parvifolius*. However, there was no significant difference in the percentage of aborted pollen between any of the diploids and the tetraploids of the same parentage. For the interspecific hybrids of blackberries and for hybrids between blackberries and raspberries (Tables I-C and II) the percentage of aborted pollen ranged from less than 30 to 95. The tetraploid interspecific hybrids between blackberries (6x) and red raspberries (2x), namely, Logan x Oregon No. 62, Logan x Oregon No. 189, and Agate Beach x Taylor were all highly sterile. The four pentaploid groups (6x x 4x), Logan x Jumbo, Logan x Oregon Evergreen, Brunstetter x Taylor, and Eldorado x Boysen, varied from 27.5 per cent to 95 per cent of aborted pollen. Brunstetter x Taylor is a blackberry x raspberry cross and is highly sterile. The other pentaploid hybrids are much more fertile. Both of the septaploid progenies had about 50 per cent good pollen and both were crosses between quite dissimilar blackberries.

Drupelets per Berry:—Though the colchicine-induced tetraploids studied did not have more aborted pollen grains than their related diploids, fewer drupelets set per berry (Table III and Fig. 2, C and D) than would be expected on the basis of amount of aborted pollen grains. The number of drupelets per berry in the tetraploid fruits was only 15 to 30 per cent of that of the diploids.

TABLE III—COMPARISON BETWEEN DIPLOID AND TETRAPLOID RASPBERRIES FOR SELECTED MORPHOLOGICAL CHARACTERS

Cross	Chromosome* Number (2n)	Mean Number of Drupelets Per Berry			Mean Calyx Diameter			Mean Leaflet Shape Index†		
		Number Plants	Number Berries	Number Drupelets	Number Plants	Number Calyces	Diameter Calyx	Number Plants	Basal Leaflets W/L	Terminal W/L
Taylor × *Rubus parvifolius*	14	8	61	8.2	15	83	18.1	4	0.71	0.58
	28	5	66	11.2	3	34	29.6	7	0.83	0.75
1202 × Taylor	14	5	32	47.9	10	60	16.5	2	0.66	0.56
	28	5	78	15.0	5	61	20.4	4	0.85	0.80
Cumberland × Imperial	14	1	4	74.5	10	50	17.1	1	0.72	—
	28	—	—	—	5	25	19.2	2	0.83	—
Taylor × Imperial	14	1	5	60.4	1	5	15.3	1	0.67	—
	28	1	12	20.8	1	5	20.1	1	0.80	—
No. 8 (Lloyd George × Ranere) × Pynes Royal. . .	14	1	5	69.0	—	—	—	1	0.68	—
	28	1	5	12.2	—	—	—	1	0.85	—

*The chromosome number of several of these plants was verified by examination of meristematic cells of shoot apexes and roots. The known chimeric condition of several plants may result in the introduction of some slight error, some sectors not being completely tetraploid.

†Width divided by length.

Size of Calyx:—The diameter of 5 to 10 representative calyces from the plants of each progeny listed in Table III was measured and the tetraploids were found to have calyces ranging from 1.1 to 1.6 times the diameter of those of the diploids and also to have wider and thicker sepals. In Fig. 2-A calyces from a tetraploid sector are compared with

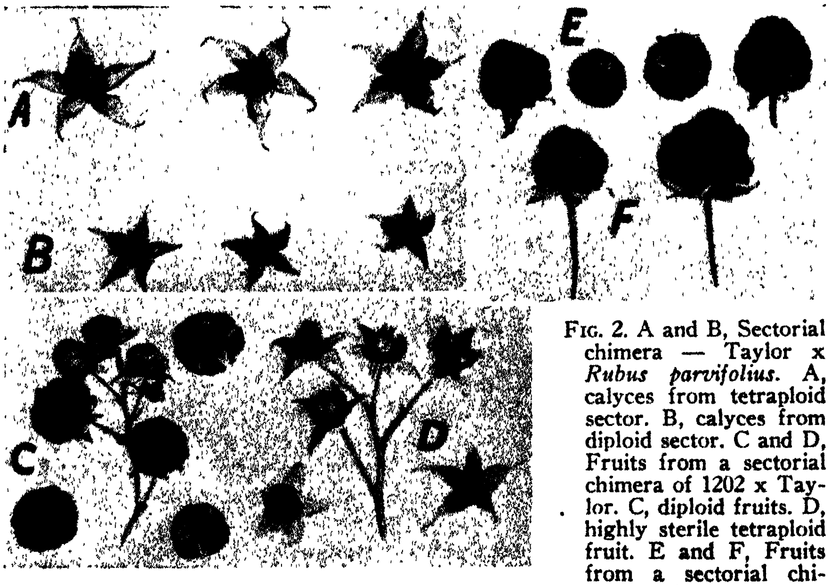

FIG. 2. A and B, Sectorial chimera — Taylor x *Rubus parvifolius*. A, calyces from tetraploid sector. B, calyces from diploid sector. C and D, Fruits from a sectorial chimera of 1202 x Taylor. C, diploid fruits. D, highly sterile tetraploid fruit. E and F, Fruits from a sectorial chimera of Taylor x Imperial (4–P–2). E, diploid fruit. F, fruit from tetraploid sector. Note difference in drupelet size and length of peduncles.

calyces from a diploid sector of the same plant. In Fig. 2, C and D a comparison of drupelet and calyx size of diploid and tetraploid berries is shown.

Calyx size in individuals of the Taylor x *Rubus parvifolius* cross was variable, many plants having fairly large calyces. However, both the parental forms involved in this cross possessed exceptionally large calyces, their diameters being, respectively, 22.3 and 21.7 millimeters. It was evident that the large calyces of some plants were the result of the quantitative inheritance of calyx size factors rather than from doubling of the number of chromosomes.

Leaflet Shape:—Observations indicated that the leaves of tetraploid plants differed in shape from those of diploids. Measurements were made of the length and width of about 10 mature leaves per plant, selected from the midportion of vigorous young shoots. A basal leaflet was measured and in cases where the leaves had five leaflets, similar measurements were made of the terminal ones. The shape index, as presented in Tables III and V, represents the ratio of width to length. The results for basal and terminal leaflets are presented in separate columns. In all cases the tetraploid leaflets were found to be broader and rounder as well as generally more wrinkled than the diploid ones (Fig. 3).

Similar effects of chromosome doubling on leaf shape have been reported by Dermen and Bain (4). Sinnott and Blakeslee (2) also describe a shape change in fruits of Cucurbita and Datura resulting from chromosome doubling.

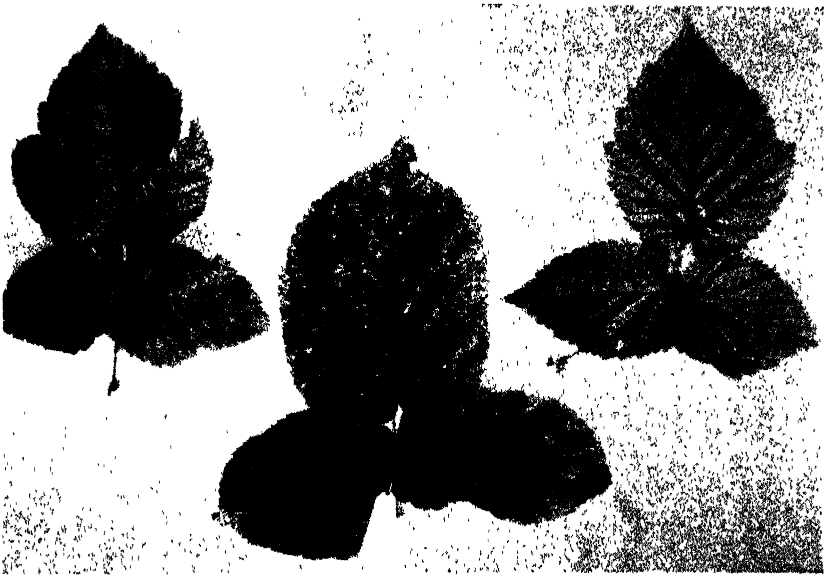

FIG. 3. Leaves of tetraploid and diploid plants from the cross 1202 x Taylor. Leaves at right and left from diploid plant (36–P–11). Central leaf from tetraploid (36–P–8). Note the difference in size and roughness.

Seed and Drupelet Size:—The seeds of tetraploid seedling raspberries were from 1.3 to 1.7 times as heavy as those of the comparable diploids (Table I and Fig. 4). Seeds from sectorial chimeras showed somewhat greater differences, the 4x seed being 1.5 to 1.8 times as heavy as diploid seed from the same plant. Besides this increase in seed weight, a corresponding increase in drupelet size was observed as a result of chromosome doubling (Fig. 2, F).

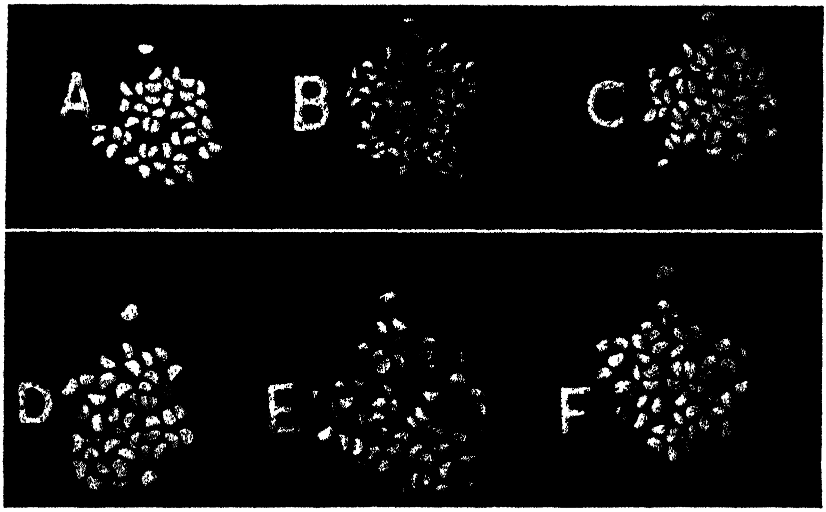

FIG. 4. Seed from sectorial chimeras. A, B, and C, from diploid sectors. D, E, and F, from tetraploid sectors. A and D, No. 1202 x Taylor (34–P–4); B and E, Taylor x Imperial (4–P–2); and C and F, No. 8 (Lloyd George x Ranere) x Pynes Royal (48–P–1). For relative seed weights from these sectors, see Table V.

To determine whether or not the heavier seed weight of the tetraploids was a result of the increased sterility, the relationship in untreated plants between number of drupelets per berry seed and drupelet weight was studied. Data were obtained for Early Harvest and

TABLE IV—COMPARISON OF SEED AND DRUPELET WEIGHT OF BERRIES WITH FEW AND WITH MANY DRUPELETS FROM UNTREATED PLANTS OF EARLY HARVEST (2x) AND ELDORADO (4x) BLACKBERRIES AND OF TAYLOR (2x) RED RASPBERRY

Variety	Number Berries	Average Number Drupelets Per Berry	Calculated Weight of 100 Seed ± S. E. (Mg)	Average Weight of One Drupelet (Mg)
Early Harvest	10	36.6	120	26.1 ± 1.5
	10	5.3	120	35.0* ± 4.4
Eldorado	10	68.7	230 ± 0.002	43.5 ± 2.5
	10	7.3	300† ± 0.013	76.7‡ ± 5.9
Taylor	3	53.0	143	28.8
	4	31.5	144	30.8

*The difference between the two means = 8.9 ± 4.7.
†The difference between the two means = 70.0 ± 13.0 and is significant.
‡The difference between the two means = 33.2 ± 6.4 and is significant.

Eldorado blackberries and for Taylor red raspberry (see Table IV). For the two diploids, Early Harvest and Taylor, berries with great differences in number of drupelets had relatively slight differences in weight of drupelets and no difference in seed weight. For the tetraploid Eldorado, however, berries with very few drupelets had significantly larger drupelets and seed than those with many drupelets. The increase in seed size noted in the variety Eldorado emphasizes the importance of using several criteria in selecting tetraploid plants from mixed population previous to confirmation by chromosome counts. Bailey (1) has observed that drupelet size of Rubus depended upon conditions of soil, moisture, and exposure under which the plant grew. Morris (5) reported a seed weight of 258 milligrams per 100 seed for normal fruit and 278 milligrams for 100 seed of defective fruit of Lawton. His normal and defective fruit was similar to that of Eldorado in Table IV with 73.0 versus 6.2 drupelets for the two classes. Seed size does seem to be affected sometimes by environmental conditions.

Sectorial Chimeras:—In Table V is given a comparison of some of the characteristics of diploid and tetraploid sectors of five plants. For the most part, these data show the same differences as do the data for entire plants as given in Tables I, II, and III. Leaf shape, calyx size, pollen size, and seed size are all characters indicative of polyploidy.

TABLE V—COMPARISON OF CHARACTERISTICS OF TETRAPLOID AND DIPLOID SECTORS OF FIVE PLANTS

Cross	Chromosome Count of Sector	Mean Calyx Size		Mean Leaflet Shape Index		Mean Pollen Diameter (Microns)	Per Cent Aborted Pollen	Mean Weight of 100 Seed ± S. E. (Mg)	Mean Number Drupelets Per Berry
		Diameter (Mm)	Width (Mm)	Basal W/L	Middle W/L				
1202 × Taylor 34-P-4	14	15.9	3.8	0.71	0.58	—	—	138.0±5.7	42.5
	28	21.7	5.6	0.91	0.83	36.0±0.5	20	209.5	16.8
1202 × Taylor 36–P-21	14	14.8	3.6	0.67	0.59	27.0±0.5	—	129.0	35.0
	28	20.7	4.9	0.91	0.77	35.5±0.5	35	236.1	4.8
Taylor × Imperial 4-P-2	14	15.3	3.7	0.67	—	—	30	106.2	60.4
	28	20.1	5.5	0.77	—	37.0±0.5	—	188.8	20.8
No. 8 (Lloyd George × Ranere) × Pynes Royal 48–P-1	14	—	—	0.67	—	—	—	158.9	69.0
	28	—	—	0.83	—	28.0±1.0	—	248.8	12.2
Taylor × *Rubus parvifolius* 24–P–8	14	22.8	4.2	—	—	—	—	—	—
	28	34.4	6.3	—	—	—	—	—	—

DISCUSSION AND SUMMARY

As a result of colchicine treatment of 2,500 seedlings, full tetraploidy as well as sectorial and periclinal chromosomal chimeras were induced in various hybrid populations of raspberries. Seventeen partially or completely tetraploid plants were found among seedlings of the following crosses:

1. *Rubus idaeus* x *R. strigosus* (Taylor (red) x *R. parvifolius* (trailing red))—nine seedlings.

2. No. 1202 (Potomac (purple) x Latham (red)) x Taylor — four seedlings.
3. *Rubus occidentalis* (Cumberland (black)) x *R. idaeus* (Imperial (red))— one seedling.
4. (Lloyd George x Ranere) x Pynes Royal — one seedling.
5. Latham x Red Cross — one seedling.
6. Cumberland black raspberry (open pollinated)— one seedling.

Leaf size and thickness and calyx size are the most obvious characters for differentiating tetraploids and diploids. If supplemented by measurements of pollen and seed, probably most of the tetraploids can be distinguished without chromosome counts. These tetraploids do not have the fruit size, fall fruiting, and in some cases the disease resistance and the smooth leaves of the known tetraploid varieties Hailsham, La France, and Colossus. However, they do represent new genetic tetraploid raspberry material for use in breeding.

The doubling of the chromosome number in the interspecific hybrid Taylor (*Rubus idaeus* x *R. strigosus*) x *R. parvifolius* did not result in a measurable increase in fertility. However, although untreated progenies of this cross do not usually give fertile seedlings, fertile plants of this cross have been selected. It is evident then that the chromosomes of the two parents are sufficiently homologous to result in good pairing (at times, at least) and an increase in fertility due to amphidiploidy would not necessarily be expected following chromosome doubling.

Though the seed size of the tetraploids is appreciably greater than that of the diploids, it is not greater than that of many important commercial varieties of blackberries.

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Identification of Certain Red and Purple Raspberry Varieties by Means of Primocanes[1]

By O. C. Roberts, *Massachusetts State College, Amherst, Mass.,* and A. S. Colby, *University of Illinois, Urbana, Ill.*

INVESTIGATIONS by Shaw (1), Shaw and French (2), and Upshall (3) have demonstrated that certain tree fruit varieties can be recognized solely by vegetative characters. Thus, methods of identification have been perfected to the point that trained workers are able to positively identify varieties which may occur in mixtures in the nursery row.

The work with tree fruits suggests the question, "To what extent can bramble varieties be identified solely by vegetative characters of the primocanes?" Grubb (4) and Winter (6, 7) have recognized the possibility of identifying raspberry varieties utilizing both floricanes and primocanes.

During the past two seasons a study of 30 red and purple raspberries indicate that these varieties may be identified positively by the vegetative characters of the primocanes alone. This conclusion is based on a study of primocanes of the same varieties grown at Amherst, Massachusetts; Geneva, New York; New Carlisle, Ohio; Lafayette, Indiana; Urbana, Illinois; Villa Ridge, Illinois; and Lexington, Kentucky.

While the economic value of identifying varieties prior to fruiting may be less important with brambles than with tree fruits, observations by Grubb and Peren (5) and the authors indicate that varietal mixtures are distributed by some nurserymen, which may cause considerable annoyance as well as financial loss to the bramble fruit grower. For example, in the spring of 1942 Newburgh plants, obtained from a prominent nurseryman, were set in a new plantation at Massachusetts State College. After the primocanes had attained sufficient growth to make identification possible, plants of Golden Queen, Viking, and Chief were discovered mixed with Newburgh. Mixtures also were found in two other varieties. Thus, it is apparent that there is a need for some means whereby such mixtures can be eliminated in the nursery or field *before* the plants have become permanently established. Obviously, the greatest practical advantage will be obtained if such mixtures are recognized before the plants reach the floricane stage. Identification by means of primocanes appears to be a practical procedure.

The identification of fruit plants by vegetative characters is dependent upon the fact that very rarely if ever are two seedlings identical. While typical plants of two varieties may be practically identical in many ways, they always differ in some manner. The problem of the investigator in this field is to determine the characteristics of a typical plant of each variety and then note wherein one variety differs from another. However, variations from the normal due to environmental conditions must be determined and given due consideration in varietal identification work.

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[1] Contribution No. 474 of the Massachusetts Agricultural Experiment Station.

The description and segregation of characters which are practically constant under all conditions of soil or culture is basic to all other considerations. However, characters which may be modified should not be ignored.

Observations during the growing season indicate that certain traits such as prickle color and number, cane pubescence, and leaf serrations are dependable for a particular variety from the time a primocane has reached a height of 18 to 20 inches until about the middle to last of September.

CHARACTERS WHICH HAVE BEEN FOUND MOST DEPENDABLE

1. The Nature of the Prickles:—Of all the distinguishing characters studied, none appeared to be more consistent under all conditions throughout the season than that of the prickles. There are generally marked differences in the nature of the prickles among the several varieties. Prickles vary with respect to total number, color, relative number between the basal and distal portions of the cane, length, and degree of stiffness. In addition, differences in both color and shape of the base of the prickle frequently serve as a means of distinguishing varieties. Thus, Washington with numerous prickles, especially at the tip of the cane, may be distinguished readily from Tahoma which has fewer and shorter prickles. Likewise the purple color at the base of the prickles separates Indian Summer from Latham.

In the mixtures mentioned above, the several varieties were distinguished chiefly by means of prickle characters.

2. Cane Color, Amount of Bloom, and Pubescence:—Differences in cane color, and/or amount of bloom are particularly pronounced on certain purple varieties (Fig. 1). For example, primocanes of Sodus, which carry a heavy coat of bloom, may be distinguished from those of Columbian, Potomac, and Ruddy with an intermediate amount of bloom, and from those of Marion with none at all. Such absence of bloom on Marion causes the canes of this variety to appear dull and green. Many red varieties also exhibit marked differences in these respects together with the presence or lack of pubescence. Thus, the glabrous, glaucous canes of Taylor separate this variety from Marcy, the canes of which are pubescent and not glaucous. Such cane characters are relatively constant for a particular variety until that time in the autumn when primocanes are inclined to acquire more or less red color.

3. Shape of Primary Leaves:—A raspberry leaf is composed of a primary or terminal leaflet and one or two pairs of lateral leaflets. While the leaves throughout a primocane may exhibit considerable variability, the primary leaflets on the mature leaves near the growing tip are sufficiently characteristic of a particular variety to be useful aids in identification. These leaflets vary, according to variety, in length and width of blade, and width of base and apex. The relatively narrow leaflet of Cuthbert compared with the broad leaflet of Chief distinguishes these two varieties (Fig. 2).

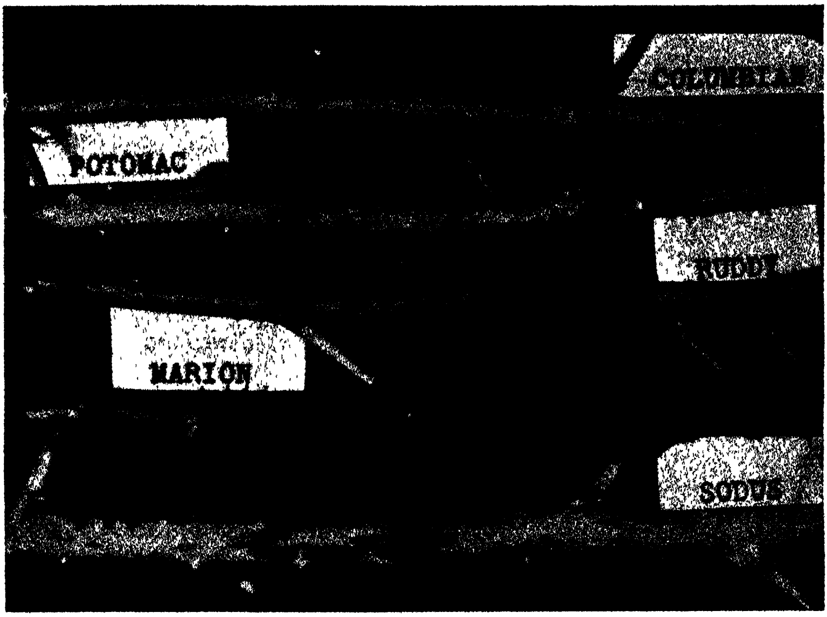

Fig. 1. Primocanes of five purple raspberry varieties, showing characteristic amounts of bloom. Heavy bloom on Sodus; no bloom on Marion; moderate amounts on Ruddy, Potomac, and Columbian.

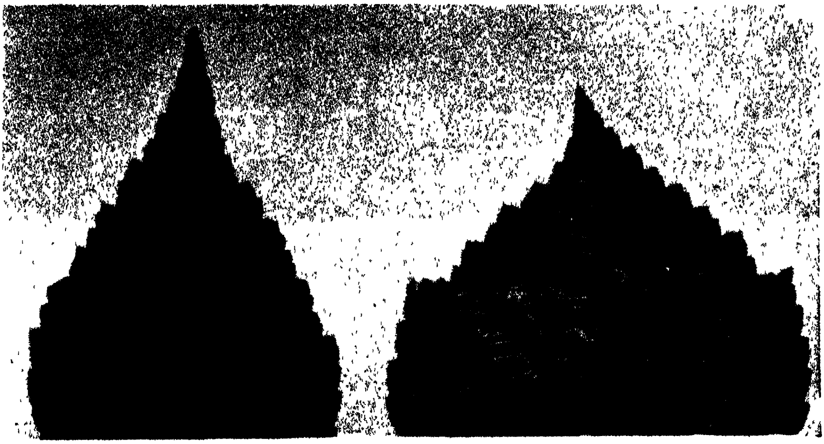

Fig. 2. Tips of terminal leaflets of Cuthbert (left) and Chief (right) red raspberries, illustrating relative leaflet width.

Characters Which Are Secondary in Importance

Even characters which are somewhat variable may be useful aids in identification. Some distinguishing differences which may be included in this group are:

1. *Number of Leaflets:*—With many varieties leaves having both

three and five leaflets may be found on the same primocane. In such instances the number of leaflets is of little value for identification purposes. However, the leaflets of some varieties are usually three in number while in others they are generally five. Thus, it is possible to separate certain varieties on this basis. Primocanes of Washington are commonly pentafoliolate while those of Chief are generally trifoliolate.

2. *Fold of the Leaves:*—While the leaves of many varieties are flat, others exhibit varying types of folding which may be characteristic for a particular variety. Types of folding may vary with different varieties from a reflex folding of the leaf margin to a broad U-fold and even, in some instances, to a relatively narrow V-fold. Chief, which has a broad flat leaf, can be distinguished from Newburgh (Fig. 3) which has a narrow V-fold leaf. In some instances the leaves are inclined to be cupped as with Van Fleet. Further study of this leaf peculiarity may indicate that it is sufficiently reliable to be placed in the group of characters which are most dependable.

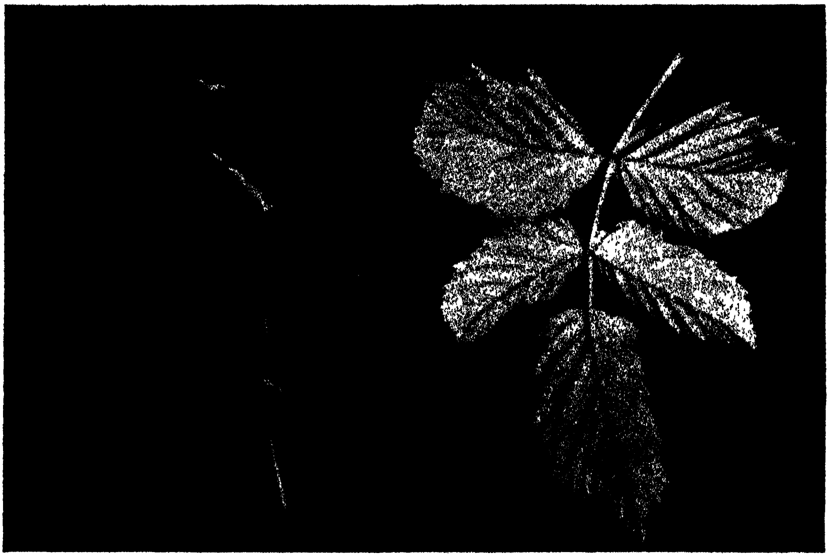

FIG. 3. Leaves of Newburgh red raspberry — upper and lower surfaces — illustrating typical V-folding leaflet type, and rugosity.

3. *Rugosity of the Leaves:*—Leaves of certain varieties may be relatively smooth, that is, free from wrinkles, while those of others may be decidedly wrinkled with some showing intermediate degrees of rugosity. The amount within a variety seems to be relatively constant. Thus, it is possible to segregate varieties into three groups arbitrarily, first by listing varieties like Van Fleet as having smooth leaves while those like Newburgh have very rugose foliage. Varieties like Sunrise with an intermediate degree of wrinkling would be classified as slightly rugose.

4. *Leaf Margin:*—Differences in the character of leaf margins are not as pronounced as those of many other parts of the leaf, yet variations have been observed in the shape of the serrations of certain varieties which distinguish them from all others. Thus, the leaf type of Newburgh with fine, sharp serrations separates this variety from Ranere, the leaves of which have coarse, dull serrations.

5. *Petioles:*—Occasionally, differences in the character of the petioles are sufficient to separate one variety from another. These differences may be expressed by the presence or lack of pubescence and the number and structure of the prickles. Ohta, which has many prickles on the petiole, can be distinguished from Lloyd George which has few prickles.

6. *Leaf Pose:*—While the pose of the leaves with most varieties is too similar to differentiate one from another, a few varieties have such a distinctly characteristic leaf pose—either erect or drooping—that identification is facilitated by this means. The leaf pose of Latham is erect while that of Washington is drooping.

CHARACTERS WHICH ARE RELATIVELY UNIMPORTANT

1. *Color of Leaves:*—While the color of the foliage of a particular variety may be characteristically darker or lighter than that of some other, variation due to environmental conditions may readily alter the color so that it loses whatever value it might have had as a distinguishing character. However, under similar conditions, the leaves of Latham are normally dark green, those of Cayuga are yellowish green, while those of Viking are a clear, dull green.

2. *Cane Vigor:*—Unquestionably, certain varieties tend to produce canes which excel others in diameter and length and, in some instances, this characteristic may be helpful in recognizing a particular variety, but variability in cane growth due to cultural conditions limits the extent to which vigor may be used for identification purposes. The canes of Sodus are characteristically more vigorous than those of Columbian.

3. *Pubescence on Lower Leaf Surface:*—A more or less characteristic amount of pubescence on the under leaf surface has been observed on several varieties, and appears to be a relatively constant character of a particular variety. The use of this peculiarity for identification purposes is limited by the slight differences between the amount of pubescence present on one variety and that of another. When compared side by side, Marcy appears to have more pubescence on the under surface of the leaves than Taylor.

4. *Color of the New Tip Leaves:*—With few exceptions tip color appears to be too variable to be of particular value in identification of varieties. However, Chief can be identified from all other varieties studied by the peculiar bronze color of the tip leaves which persists throughout most of the growing season.

5. *Habit of Growth:*—By the latter part of the growing season many varieties tend to exhibit peculiar habits of growth. Some are inclined to branch more than others. Also, the canes of some varieties tend to be erect while others droop to varying degrees. These character-

istics often serve as valuable guides in suggesting the identity of a variety but can seldom be used alone to distinguish one variety from another. However, Tahoma with its relatively erect habit of growth is readily distinguished from Washington with its drooping habit. Likewise, Latham with few branches can be distinguished from Ranere and Newburgh with their many branches.

SUMMARY

Thus far in this study emphasis has been placed on identification of certain raspberry varieties by means of characters which may be observed without the aid of a lens since the objective of this work has been to determine the possibility of quickly and easily identifying mixtures in the row. This can be accomplished only if readily visible differences are present in sufficient numbers and combinations to make identification of varieties possible. Observations by the authors indicate that identification of red and purple raspberries by means of vegetative characters of the primocanes is entirely possible and feasible. Whether or not the same conclusions are justified for black raspberries can be determined only by further study.

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Fertilizer Responses of Black Raspberries in Western New York in Demonstrational and Experimental Layouts[1]

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FOR several years there has been an increasing interest in growing black raspberries in certain sections of western New York. The rich flavor of this fruit is making it increasingly popular as a dessert fruit, as a source of juice, either alone or blended with other fruit juices and as a flavor for various types of frozen confections. This increasing demand has also resulted in better prices to the growers.

In one section of the western part of the State in particular this fruit has been grown for many years and a large proportion of the crop dried for pie stock. The section referred to is known as the Bristol area and is located in the valleys and on the rather steep slopes west of Canandaigua Lake, one of the well-known Finger Lakes of western New York. Production in this area in years past has fluctuated with prices. Formerly high prices prevailed for the dried berries but have fallen off in more recent years, so that other outlets such as fresh fruit and frozen fruit markets have had to be found. These facts together with lowered yields due to neglect, disease, and to older and less productive varieties caused a gradual decline in the industry in this Bristol region. Probably also soil erosion on some of the steeper slopes utilized for this crop has contributed to this gradual deterioration.

Farm manure is used on this crop by some of the growers but no systematic provision for soil organic matter is made and only a small proportion of the growers use commercial fertilizer. This general decline was the basis for the demonstrational work here reported on this crop in this area.

DEMONSTRATION LAYOUT

In 1940 a simple nitrogen demonstration was laid out on seven 200 foot rows of Cumberland just coming into bearing and nine rows of older Kansas. The soil is an Ontario loam and had been in alfalfa for several years, in fact was a more productive one than the authors would like to have had. The rows are 7 feet apart and the plants 2½ feet in the row giving some 80 plants per plat. Nitrate of soda alone was used and at two rates, namely 200 and 300 pounds per acre. It was applied broadcast in spring just before growth started over a 4-foot area, that is 2 feet on each side of the plants. Fairly regular cultivation up to some time before harvest was the method of culture and no cover crops were employed. On Kansas the 200 and 300 pound rates and no-treatment were each replicated three times, while on Cumberland, only the 300 pound rate was used, similarly replicated.

The demonstration was run 2 years and although the yields of both varieties showed definite response to nitrate of soda, the results were not too clear cut, in some cases the no-treatment rows outyielding the treated ones and with no consistent difference between the two rates of application. This was apparently due to differences in soil productivity since soil erosion seemed to be more marked on the rows farther down the slope where the percentage of slope was somewhat greater. No differences in size of berries or in number and size of canes could be demonstrated, although many berries were counted and weighed and every new cane in the block was calipered in the fall after growth had ceased. With the trends and leads secured through these two years of demonstration a more comprehensive layout was then planned.

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[1] Journal Paper No. 539, New York State Agricultural Experiment Station, Geneva, N. Y., January 5, 1943.

Experimental Layout

In the spring of 1942 the Cumberland block only, since it was younger, more uniform and more vigorous, was laid out in an experiment more in keeping with modern field experimental technic. Each of the 200-foot rows was divided into four equal sections. This gave 28 new plats each consisting of 50 feet of row and in four blocks of seven plats each. Six different fertilizer treatments along with no-treatment were randomized in each of the four blocks disregarding the two previous years' treatments. The seven plats were as follows:

Plat Treatments (Acre Basis)

1. 300 pounds nitrate of soda.
2. 240 pounds sulfate of ammonia.
3. 115 pounds Uramon.
4. 300 pounds nitrate of soda and 200 pounds sulfate of potash.
5. 300 pounds nitrate of soda, 500 pounds 20 per cent superphosphate and 200 pounds sulfate of potash.
6. 700 pounds soybean meal.
7. No fertilizer.

Table I presents the data for yields, berry size and cane growth.

Only the final result of variance analysis is given, namely the Snedecor "F" value and the measure of significance, that is the no-treatment total plus twice the standard error of the difference.

Discussion

First in regard to yields (I, Table I), fertilizer treatments gave highly significant results even at the 1 per cent point ("F" value = 5.43). Every one of the treatments was significantly superior to no-treatment. That nitrogen was the effective factor is shown by the fact that there was no significant difference due to the presence in the fertilizer of either phosphorus or potassium. The three nitrogen carriers, nitrate of soda, sulfate of ammonia and Uramon were equally effective when used in equivalent amounts of nitrogen. Soybean meal (Treatment 6) an organic source of nitrogen, although giving a significant yield increase over no-treatment was a poorer source of nitrogen than the other three carriers, and in fact gave a yield significantly below

TABLE I—DATA* ON BLACK RASPBERRY FERTILIZER EXPERIMENT (1942)

Blocks		Treatment							
		1	2	3	4	5	6	7	Totals
		Yields in Quarts Per Plat							
I	A	34.5	41.5	36.0	44.5	36.5	34.5	27.0	254.5
	B	34.5	32.0	34.5	34.5	33.5	36.5	25.0	230.5
	C	41.0	34.0	41.0	33.5	38.0	26.0	24.0	237.5
	D	36.5	43.5	39.5	32.0	37.5	31.5	24.0	244.5
Totals . . .		146.5	151.0	151.0	144.5	145.5	128.5	100.0	967.0
		Weights (Grams) 100 Berries—Mean, 12 Quarts Per Plat							
II	A	245	212	229	229	245	227	197	1584
	B	236	215	228	238	251	209	199	1576
	C	252	229	228	237	249	218	221	1634
	D	220	245	235	233	237	218	201	1589
Totals .		953	901	920	937	982	872	818	6383
		Number of Canes Per Plat							
III	A	88	98	95	97	95	98	80	651
	B	84	92	92	79	86	104	73	610
	C	96	85	92	97	99	83	71	623
	D	79	114	96	82	92	72	72	607
Totals .		347	389	375	355	372	357	296	2491
		Mean Diameter (Mm) of Canes Per Plat							
IV	A	11.9	12.8	10.5	11.8	12.0	12.9	12.2	84.1
	B	11.9	13.3	12.0	12.3	12.3	12.4	11.6	85.8
	C	14.0	13.5	13.0	13.3	13.7	11.7	10.9	90.1
	D	12.3	13.0	13.7	13.3	13.8	10.8	10.7	87.6
Totals		50.1	52 6	49.2	50.7	51.8	47.8	45.4	347.6

*All data corrected for 20 plants per plat.

Variance Analysis

The "F" values for the appropriate degrees of freedom are—5 per cent point = 2.66, 1 per cent point = 4.01.

For Yields. . . . . . "F" value = 5 43. 2 × S.E. (diff.) = 22.4. Sig. value for totals = 122.4
For Berry Size. . . "F" value = 7.87. 2 × S.E. (diff) = 55.0. Sig. value for totals = 873.
For No. of Canes. . "F" value = 2.68. 2 × S.E. (diff.) = 51.8. Sig. value for totals = 347.8
For Cane Diam. . "F" value = 1.79. 2 × S.E. (diff.) = 5.2. Sig. value for totals = 50.6

two of them. The highest yield represents an acre yield of about 4700 quarts. Nitrogen at the rate applied increased the acre yield by over 1500 quarts which at 12 cents represents a gross profit of $180 per acre at an expenditure of only $4 to $6 for fertilizer.

Next as regards size of berries (II, Table I), fertilizer effects were highly significant ("F" value = 7.87). Every treatment showed a significant difference, soybean meal, however, barely so. Here again the organic source of nitrogen was less effective than other sources, in fact significantly less than three of the other treatments. Complete fertilizer was significantly superior to three of the other treatments but not to the treatment involving the same nitrogen carrier, namely nitrate of soda.

Sulfate of ammonia and Uramon treatments dropped below nitrate of soda but not significantly so. These latter two facts will have to be verified by subsequent seasons' results. It seems quite safe to say that nitrogen not only increased yields, but also made larger berries.

The yield of raspberries depends, obviously, not only on the amount of fruit per cane but also on the number of fruiting canes. Here (III, Table II) the "F" value is only slightly larger than that at the 5 per cent point, but indicates that fertilizers had a significant effect on the number of canes per plat or per plant. In fact all the treatments were significantly better than no-treatment. There were, however, no significant differences among the treatments, even soybean meal being as effective as the other nitrogen carriers. Obviously it is nitrogen again which has been the factor in producing more canes.

Finally, analysis of cane diameter in Section IV shows a non-significant "F" value and only a slight increase over no-treatment in three cases. Although this is true, the fact that every fertilizer treatment gave mean cane diameters slightly larger than no-treatment indicates a trend at least toward thicker or more robust canes due to nitrogen. This trend may become more pronounced on repetition.

A study of individual plat performance in relation to the previous treatments of 1940 and 1941 shows that there was not only very little residual effect of the nitrate of soda given in those two years, but also that the splitting and randomization of the plats proportioned the replicates fairly well between the formerly treated and untreated rows.

From the practical standpoint the results show a highly worthwhile return for money invested in nitrogen for black raspberries, even on what may be considered a quite productive soil. From the experimental or technical standpoint it is significant that through a very simple change in experimental layout, the same area yielded much cleaner cut and dependable results and permitted a trial with six instead of two fertilizer treatments. If the seven rows of Cumberlands had been laid out in the latter way originally in 1940, the experiment would have been much more valuable and considerable time saved. The interpretations made are, of course, subject to the usual limitations incident to specific local conditions and a short experimental period. The work is being continued.

Breeding Rust Resistant Black Currants[1]

By A. W. S. HUNTER and M. B. DAVIS, *Central Experimental Farm, Ottawa, Ontario*

BLACK CURRANTS have always been moderately popular in Canada, probably more popular than in the United States. Demand for this fruit has recently been stimulated by the discovery of its high vitamin C content. Successful expansion of the black currant industry will probably depend upon the development of varieties that are resistant to foliage diseases. The most important of these diseases is undoubtedly white pine blister rust (*Cronartium ribicola* F. de Wal.) which causes much damage to the black currant plant and is responsible for the restriction of currant culture in certain areas of commercial white pine production.

A search for suitable varieties to use in breeding for rust resistance in black currants was begun at Ottawa in 1935. One bush in the Ottawa plantation has never shown any signs of rust infection. It has been identified as *Ribes ussuriense* Jancz. and is either immune or highly resistant. It is of vigorous habit but the fruit is small and unpalatable. Several plants of so-called Colorado currant, tentatively identified as *R. aureum* Pursh. and *R. odoratum* Wendl. were the least susceptible of the remaining varieties in the plantation. Crosses were made in 1938 and 1939 between the above plants and the standard varieties Boskoop Giant and Kerry, both of which are derived from *R. nigrum*.

The seedlings from these crosses have never been sprayed and were examined in the field for disease in 1941 and 1942. The year 1941 was a poor one for rust development at Ottawa, but 1942 was favourable and the susceptible plants were easily recognized. Some variation in the degree of infection of susceptible seedlings was observed in mid-August but by the middle of September this variation had disappeared and all the susceptible plants were almost completely defoliated.

TABLE I—SUMMARY OF OBSERVATIONS ON RUST INFECTION IN CROSSES UNDER OBSERVATION

Cross	Total Number Seedlings Grown	Number of Seedlings With Rust
Ribes ussuriense × Boskoop Giant	45	0
Ribes ussuriense × Kerry	168	0
Kerry × *Ribes ussuriense*	130	6
Kerry × *Ribes sp.* (prob. *aureum*)	12	5
Boskoop Giant × *Ribes sp.* (prob. *odoratum*)	20	20

The inheritance of rust resistance in the black currant has not yet been studied in detail, but resistance appears to be dominant to susceptibility, as was suggested by Hahn (1) in the case of the red currant Viking. The plant of *Ribes ussuriense* used in the above crosses is apparently homozygous resistant. The plant assigned to

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[1] Contribution No. 605, Experimental Farms Service, Central Experimental Farm, Ottawa, Ontario.

R. odoratum appears to be homozygous susceptible and the plant assigned to *R. aureum* heterozygous susceptible. Further work will be done on the inheritance of rust resistance in these plants. The presence of susceptible seedlings in the progeny of Kerry x *R. ussuriense* is probably due to accidental self pollination.

Only a few of the seedlings have fruited to date but all have shown a marked resemblance in fruit characteristics to their cultivated parent. One has been particularly outstanding. It bears its fruit in long racemes of from 6 to 12 berries, all of which ripen before any begin to drop. Jam made from this fruit is of excellent flavour and texture and the fresh berries are equal to other black currant varieties in vitamin C content.

Most of these seedlings are susceptible to powdery mildew (*Sphaerotheca mors-uvae* (Schw.) B and C.) Many of them are very susceptible but some are only slightly affected. The latter may be useful in breeding for resistance. Susceptibility to powdery mildew is not correlated with susceptibility to white pine blister rust. There is no variation between the different crosses in degree of susceptibility to powdery mildew.

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Some Effects of Cross-Pollination Versus Self-Pollination in the Cultivated Blueberry[1]

By E. B. MORROW, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

THE response of the cultivated blueberry to self-pollination was first reported by Coville (2). His work indicated that the set of fruit was less from self-pollinated flowers and that the berries were smaller and later in maturing than those from cross-pollinated flowers. Later, Merrill (4) found under Michigan conditions that self-pollination gave a satisfactory commercial set of fruit for the principal varieties grown in that region. All varieties investigated were self-fruitful. Merrill and Johnston (5) reported that berries from self-pollinated flowers matured during the normal fruiting season and were fully as large as berries resulting from open pollination. Bailey (1) of Massachusetts reported that self-pollinated flowers set a much lower percentage of berries than flowers exposed to pollination by insects. For some varieties the set was extremely low. He concluded that self-pollination could not be relied upon to give consistently good commercial crops. White and Clark (6), in New Jersey, found that for most of the varieties studied the set from self-pollination was not significantly different from the set in open-pollinated flowers. They also found that the berries from self-pollinated flowers were smaller and later in maturing than berries resulting from open pollination.

In view of these variable results, it seemed desirable to include pollination studies in the blueberry breeding program for North Carolina. Since North Carolina growers are interested in early-maturing large-sized fruit, any method of producing earlier and larger berries would be of great practical value to the commercial industry in the eastern part of the state. This paper presents data on fruit and seed size, and on time of maturity for three varieties under greenhouse conditions.

METHODS

Plants were brought into the greenhouse on February 3, 1942 after having been exposed to a temperature below 45 degrees F for 1,000 hours. To eliminate plant to plant variation, paired shoots on individual plants were used for the comparison of selfed with crossed flowers. Shoots of about equal size and with approximately the same number of fruit buds per shoot were selected for each pair. The number of pairs per plant varied from 5 to 10, depending upon the size of the plant. The treatments included Scammell x Weymouth and Scammell selfed, Weymouth x Taylor and Weymouth selfed, and Dixi x Rubel and Dixi selfed. To obtain some measure of plant to plant variation, a minimum of three plants was used for each variety.

The flowers on one shoot of each pair were self-pollinated and those on the other shoot cross-pollinated. In general, 12 to 15 flowers were pollinated on each shoot and the remaining flowers removed. On each pollination date approximately the same number of flowers were pollinated on each shoot of a pair. The cross-pollinated flowers were emasculated when the buds were almost fully grown, but before the corollas opened. Selfed flowers were not emasculated, but in some cases a portion of the corolla was removed to make the application of pollen more convenient. Pollen was applied within an hour or two after it was collected. Small strips cut from an ordinary desk blotter were used in making the pollen applications. Such strips were cut small enough to be somewhat flexible and seemed to offer less chance of injury to the pistil than a metal or other rigid type applicator. Pollen was applied immediately after emasculation and again 24 hours later to insure application during pistil receptivity. The flowers were not covered since no insect activity was observed in the greenhouse during the pollination period.

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As the fruit ripened, the berries from each shoot were placed in a separate jar and stored in a refrigerator at 40 degrees F. The berries were picked every other day, and a record was kept of the number of ripe berries from each shoot on each picking date. At the end of the picking season the number and weight of berries were obtained for each shoot. There was no decay and no apparent shrinkage when the berries were weighed and counted.

The seeds were extracted with a Waring blender. The cutting and churning action of this machine gave more thorough separation of the seeds from the pulp than hand methods previously tried. Enough water was added to cover the berries before the pulping operation was started. Operation of the machine for 20 to 30 seconds gave good separation with practically no injury to the seeds. Additional water was added, and the seeds were allowed to settle. The pulp was then decanted and the seeds washed in a few changes of water. The percentage of fully developed seeds and the average seed weight for any selfed or crossed lot were obtained by counting and weighing 10 samples of 100 seeds each.

RESULTS

Cross-pollination produced earlier ripening on all three varieties. The mid-ripening date was a week earlier for cross-pollinated berries of Scammell, 4 days earlier for Weymouth, and 8 days earlier for Dixi. The percentages of fruit harvested during the first week show the relative differences between the time of ripening of the cross-pollinated and self-pollinated berries (Table I). The inherent earliness of Weymouth is emphasized by the number of days from pollination to maturity. For the cross-pollinated flowers, this period was 48 days for Weymouth compared with 58 days for Scammell.

Cross-pollination also increased the average berry size of all three varieties (Table II). A statistical analysis of the berry weights indicates that a real difference exists between the cross-pollinated and self-pollinated berries of Scammell. To a less degree this was also true for Weymouth. The differences for Weymouth and Dixi would prob-

TABLE I—THE EFFECT OF SELF- VERSUS CROSS-POLLINATION ON TIME OF RIPENING

Pollination	Average Pollination Date	Mid-Ripening Date*	Days to Maturity	Per Cent Harvested Each Week			
				First	Second	Third	Fourth
Scammel × Weymouth ..	Mar 4	May 1	58	69	19	10	2
Scammel × Self	Mar 4	May 8	65	25	26	37	12
Weymouth × Taylor......	Mar 10	Apr 27	48	93	7	—	—
Weymouth × Self	Mar 10	May 1	52	50	43	6	1
Dixi × Rubel.	Mar 28	May 20	53	65	25	10	—
Dixi × Self...	Mar 28	May 28	61	10	45	43	2

*Indicates weighted mean mid-ripening date.

TABLE II—THE EFFECT OF SELF- VERSUS CROSS-POLLINATION ON SIZE OF BERRY

Pollination	Number of Fruiting Shoots	Flowers Pollinated Per Shoot	Berries Per Shoot	Set (Per Cent)	Mean Berry Weight (Centigrams)	Differences Necessary for Significance	
						(t = .01)	(t = .05)
Scammel × Weymouth	20	14.50	8.20	56.55	126.9	12.0	8.8
Scammel × Self. .	20	15.45	7.55	48.87	104.5	—	—
Weymouth × Taylor..	16	11.44	5.56	48.60	136.9	19.5	14.1
Weymouth × Self ...	16	13.13	5.06	38.54	120.6	—	—
Dixi × Rubel . ..	10	—	5.20	—	189.5	38.2	26.6
Dixi × Self.	10	—	4.20	—	174.2	—	—

ably have been more conclusive if more shoots had been used and more flowers per shoot had been pollinated. The increase in size of the cross-pollinated over the self-pollinated berries was 21.4 per cent for Scammell, 13.5 per cent for Weymouth, and 8.8 per cent for Dixi. The number of berries per shoot was less on the self-pollinated shoots, thus providing somewhat more favorable conditions for the development of the self-pollinated berries. In every case the percentage set was greater for the cross-pollinated flowers.

The percentage of fully developed seeds was much greater in the cross-pollinated berries, but there was no difference in size of fully developed seeds in berries resulting from self- and cross-pollinations. As indicated in Table III, very great differences occurred in the percentage of fully developed seeds between berries resulting from cross-pollinated and self-pollinated flowers of Scammell and Weymouth. The same differences also occurred in Dixi. The percentage of fully developed seeds for Dixi x Rubel was 81.2 per cent compared with 41.7 per cent for Dixi selfed. Fruit size on Scammell and Weymouth was correlated with percentage of fully developed seeds per berry. The discrepancies in size of berry between Tables II and III are due to the fact that all of the berries harvested enter into the data in Table II, while the data in Table III are based upon 50 berries taken at random from the respective lots.

TABLE III—THE EFFECT OF NUMBER OF SEEDS AND PERCENTAGE OF FULLY DEVELOPED SEEDS ON BERRY SIZE

Pollination	Number of Berries	Mean Berry Weight (Centigrams)	Number of Seeds Per Berry	Fully Developed Seeds (Per Cent)	Weight of Fully Developed Seeds (Mgs Per 100 Seeds)
Scammell × Weymouth	50	138	62	91.6	53.6
Scammel × Self	50	113	58	55.9	54.4
Weymouth × Taylor..	50	140	61	81.0	42.6
Weymouth × Self. .	50	121	45	54.0	42.7

DISCUSSION AND CONCLUSIONS

The differences in percentage of fruit set, time of ripening, and size of fruit seem to be directly related to pollen influence. The lack of differences in weight of fully developed seeds between the cross-pollinated and self-pollinated lots shows the absence of xenia, yet the differences in percentage of fully developed seeds provide an explanation of the effect shown in the time of ripening and size of fruit. The lower percentages of fully developed seeds resulting from self-pollination indicate the possibility of partial self-incompatibility such as slower pollen tube growth or the collapse of ovules soon after fertilization. An important factor in determining berry size is the number of fully developed seeds per berry. Darrow (3) and White and Clark (6) also found a correlation between the number of large, fully developed seeds and berry size. The evidence indicates that a grower might expect earlier ripening and an increase in set and size of fruit in proportion to the degree of self-incompatibility of the variety in question and to physical factors entering into cross-pollination. Since Eastern North Carolina growers are interested in early-maturing large-sized fruit, the present practice of providing for mixed variety plantings not only aids in obtaining a better set, but also helps to provide earlier ripening and a better grade of berries. On the other hand, growers in regions with a good late market such as in New Jersey and Michigan might find it advantageous to plant solid blocks of one variety, provided the decrease in set and size of fruit did not greatly reduce yield and grade of berries.

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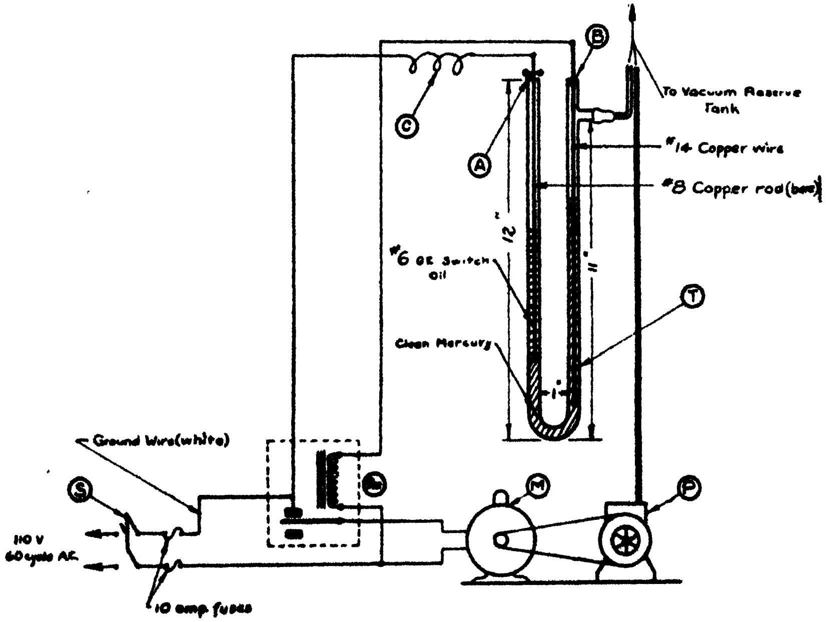
Automatic Control Apparatus for Maintaining Near-Constant Suction Pressure with an Electrically Operated Vacuum Pump

By D. V. FISHER and J. J. EMBREE, *Summerland Experiment Station, Summerland, B. C.*

THIS article describes a method of setting up simple and inexpensive equipment to maintain a near-constant suction pressure such as is required in making respiration determinations with fruit.

The materials required are: a 45-gallon gasoline barrel; a ⅛-horsepower capacitor electric motor with low starting current, 3 to 4 amperes; a small capacity vacuum pump (the smallest obtainable will be quite satisfactory); a 12-inch, ⅜-inch inside diameter glass U tube, fitted with mercury for mercury switch; a relay switch; and a quantity of rubber pressure tubing and ¼-inch copper tubing. A photograph of this apparatus is shown in the schematic diagram in Fig. 1.



T Glass U-tube (⅜" inside diam.) Heavy Gauge.
M Capacitor type ⅛ to ¼ H.P. motor with 3 to 1 V-belt drive to Pump.
P Vacuum pump (small size).
Re Relay 115V-60cycle
S Double-Pole Single-throw off-on switch
A Pinch clamp for adjustment of cut-out contact.
B Gas-tight seal (rubber cork or tubing)
C Flexible lead

FIG. 1. Schematic diagram of automatic near-constant suction pressure regulator.

The gasoline barrel serves as an air suction reservoir for feeding the air suction lines leading to different respiration chambers. It has to commend it low cost, durability, and availability. Into the delivery plug in the centre of the barrel, three copper tubes are soldered, one leading to the respiration chambers, one leading to the mercury switch, and one to the vacuum pump. When the suction pressure in the barrel falls below the required level (3 inches mercury is sufficient) the level of the mercury in the U tubes drops and makes an electrical connection. This activates the relay, starting the motor to drive the vacuum pump.

The mercury switch mentioned above consists of a glass U tube 12 inches in length about half filled with clean mercury plus 1 inch of No. 6 G.E. switch oil in the arm containing the intermittent contact copper electrode. This is to exclude oxygen in order to prevent formation of black mercuric oxide on the electrode. In the other arm which contains the electrode constantly in contact with mercury, the electrode passes first through a tight rubber stopper fitted into the end of a T tube, which is then connected to the mercury U tube. The side arm of the T tube leads to the suction reservoir barrel and thus serves to regulate the level of mercury. When the suction pressure falls below a certain value, the drop in level of mercury in the arm of the U tube connected to the suction reservoir barrel, and the corresponding rise in level of mercury in the arm of the U tube containing the intermittent-contact electrode completes the circuit, thereby activating the relay. By regulating the level at which the intermittent-contact electrode rests above the mercury by adjustment "A", whatever degree of suction pressure required may be obtained.

This apparatus is normally used to draw air continuously through not more than ten 4-gallon cans of fruit at a rate of 5 litres of air per hour for each can. The switch throws the motor on every minute, and runs the vacuum pump for about a quarter of a minute. The change in level of mercury thus obtained is so small that a fluctuation of only 2 per cent occurs.

Environment Control Cabinets for Studying the Inter-relation of Temperature and Photoperiod on the Growth and Development of Plants

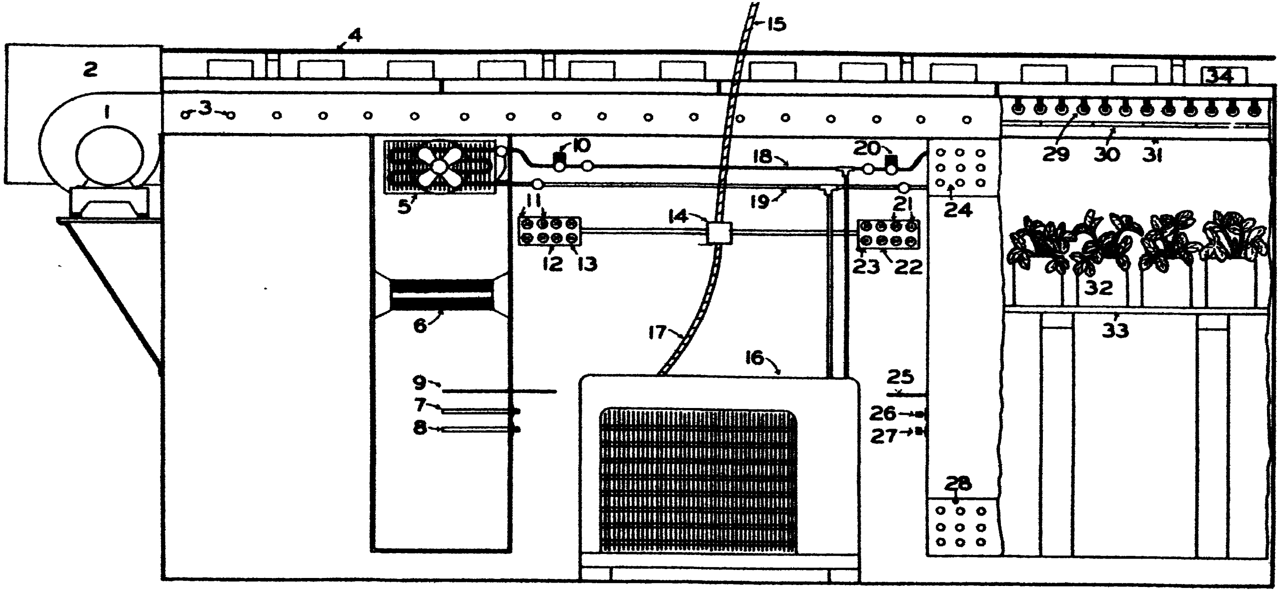
By H. T. Hartmann and L. R. McKinnon, *University of California, Davis, Calif.*

IT IS becoming established that the temperature at which plants are grown exerts a profound influence on their reaction to the length of day (2, 5, 6, 7). As these two environmental conditions are so closely related in influencing the growth and development of most plants it is necessary to include both when speaking of the effects of either one.

In order to accurately study the behavior of plants when grown under different combinations of day-length and temperature, four air-conditioned cabinets were constructed and each illuminated with banks of fluorescent lamps. With this arrangement it is possible to maintain two different temperatures and two different day-lengths thus providing four distinct growing conditions; that is, long days with high temperatures, short days with high temperatures, long days with low temperatures, and short days with low temperatures. With the equipment used the temperatures can be maintained by means of adjustable thermostats at any point between approximately 40 degrees and 100 degrees F with a variation of ± 1 degree F, while the day-lengths can be set at any desired value by means of an electric time switch.

Each cabinet was constructed of plywood on a 2 by 4 framework and then covered by a layer of Celotex for insulation. They are 3 feet in width, 4 feet in length, and 5 feet in height. At the top of each cabinet is a light loft separated from the cabinet below by a sheet of glass. The heat accumulated in the light loft from the lamps is removed by directing a constant stream of air through the loft by means of a blower. The air is passed through a 2-inch thick glass wool filter before entering the blower in order to remove dust which otherwise would accumulate on the lamps and glass.

The lamp bank in each of the four cabinets consists of 12, 40-watt, 48-inch fluorescent lamps (six "Daylight" and six "White"). This provides an approximate intensity of 500 foot candles at the tops of the plants. A higher light intensity would be desirable especially when plants are grown at high temperatures. The use of some incandescent or perhaps mercury vapor lamps in combination with the fluorescent lamps may be a practical means of increasing the light intensity. The spectral distribution of the visible radiant energy from the "Daylight" and "White" lamps (4) is shown in Fig. 5 as well as that from a 500-watt incandescent lamp (1). Also shown is Hoover's (3) curve of relative photosynthesis in relation to wave length of light. It is seen that the combination of "Daylight" and "White" fluorescent lamps emits energy having a spectral distribution which tends to approach the spectral energy requirements of photosynthesis. The lamp curves shown in Fig. 5 are drawn to peak at 100, thus the relative energy



1. "Utility" blower. ¼ horsepower motor. 500 cubic feet per minute.
2. Glass wool air filter on intake of blower.
3. Exhaust vents for air from blower.
4. Plyboard cover.
5. Unit cooler (one 1800 British Thermal Units and one 3000 British Thermal Units used).
6. Two 500-watt electric strip heaters.
7. Thermostat (heaters).
8. Thermostat (refrigeration).
9. Thermometer.
10. Solonoid valve, 110 volt.
11. 110 volt outlets, continuous supply.
12. 110 volt outlets, 15 hours per day from time switch.
13. 110 volt outlets, 10 hours per day from time switch.
14. Electric distribution box.
15. Main electric line to time switch and power line.
16. ¼ horsepower Freon refrigeration unit.
17. 220 volt supply line to compressor.
18. "Liquid" line from compressor.
19. "Expansion" line from unit coolers.
20. Solenoid valve, 110 volt.
21. 110 volt outlets, continuous supply.
22. 110 volt outlets, 15 hours per day from time switch.
23. 110 volt outlets, 10 hours per day from time switch.
24. Air inlets to cabinets.
25. Thermometer.
26 Thermostat (heaters).
27. Thermostat (refrigeration).
28. Air outlets from cabinets.
29. Fluorescent lamps (Six 40-watt "Daylight" and six 40-watt "White" per cabinet).
30. Air inlet duct from blower.
31. Glass between lamp chamber and cabinet.
32. Plants growing in gallon cans.
33. Wood platform.
34. Tulamp ballasts for fluorescent lamps.
35. Starters for lamps.
36. Air duct from blower.

FIG. 1. Diagram of rear view of environment-control cabinets.

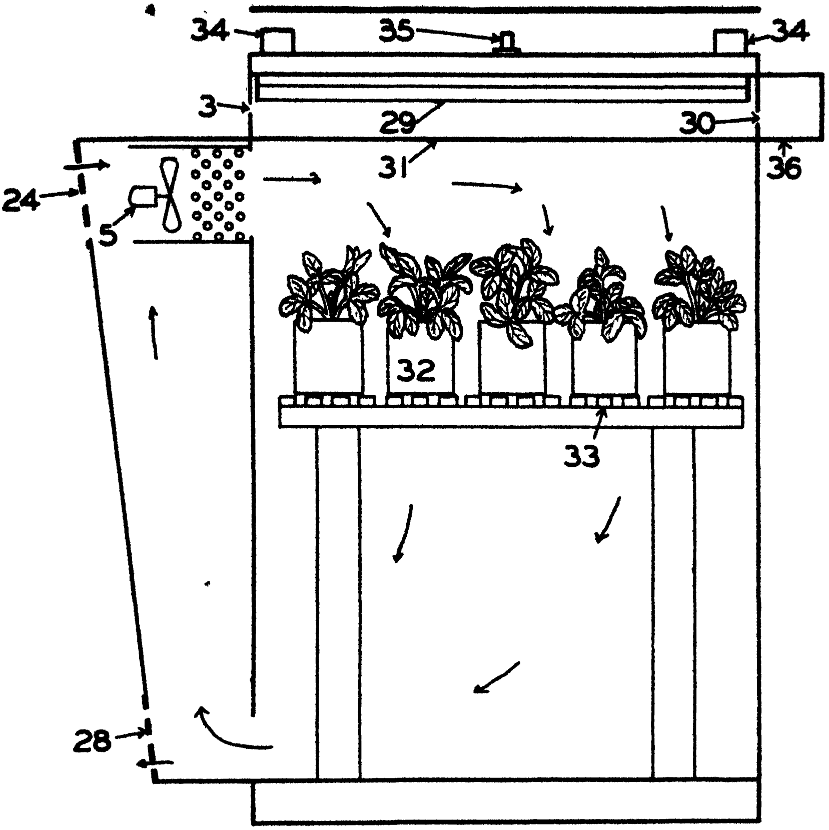


FIG. 2. Diagram of end view cross-section of environment-control cabinets. (See Fig. 1 for key.)

scale applies only to the individual curves and does not show any relation between curves.

At the rear of the group of cabinets are two air ducts, each built over the partition between two adjoining cabinets so that the air inlet and outlet of each of the cabinets passes into the common duct. The two air ducts are shown in Fig. 3. In them are mounted the "unit coolers" (which are connected to the refrigerating unit), the electric strip heaters, and four thermostats (two controlling the heaters and two controlling the refrigeration). Behind each "unit cooler" is a fan which circulates air through the ducts and into the cabinets. A system of adjustable air vents at the upper and lower part of each duct provides for a renewal of fresh air in the cabinets while most of the air is recirculated through the ducts. The movement of air is shown in Fig. 2.

The arrangement of the refrigerating equipment is shown in Fig. 1 and Fig. 3. A ¼ horsepower Freon compressor is used in conjunction with one 1800 B.T.U. and one 3000 B.T.U. "unit cooler". The cooler

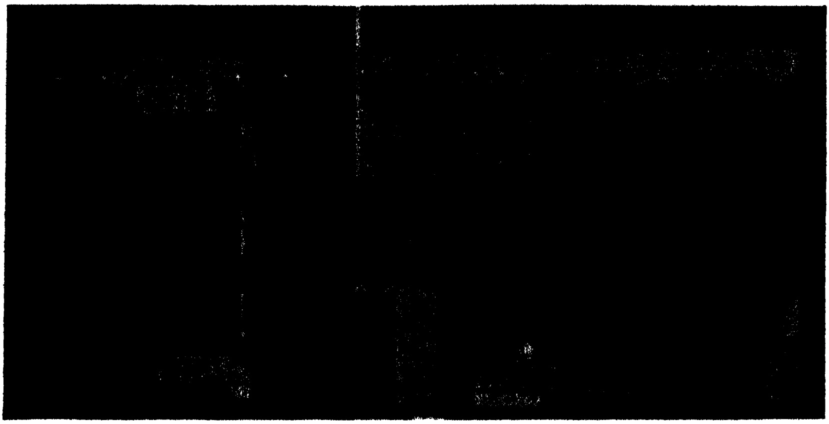


FIG. 3. Rear view of environment-control cabinets.

of largest capacity is located in the air duct of the two cabinets which are maintained at the lowest temperature.

The time switch used to operate the lamps was manufactured by the American Instrument Company and consists of a syncronized electric motor which operates two adjustable cams that make and break two separate circuits. One circuit includes the lamp banks in the two short-day cabinets while the other circuit includes the two lamp banks in the long-day cabinets in addition to the blower which operates, therefore, as long as any of the lights are on.

There is no automatic control of humidity in the present set-up. The relative humidity is maintained at approximately equal values in all the cabinets by empirically keeping water in pans on the floor of the high temperature cabinets until the relative humidity reaches the level found in the low temperature cabinets.

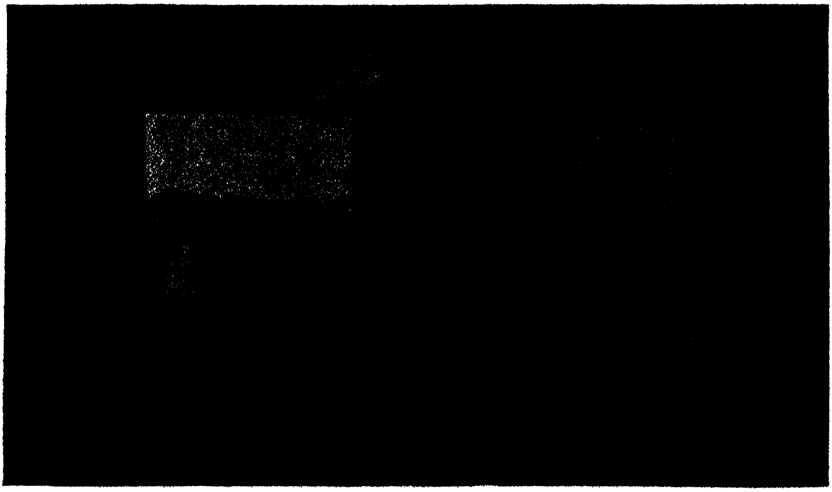


FIG. 4. Front view of environment control cabinets.

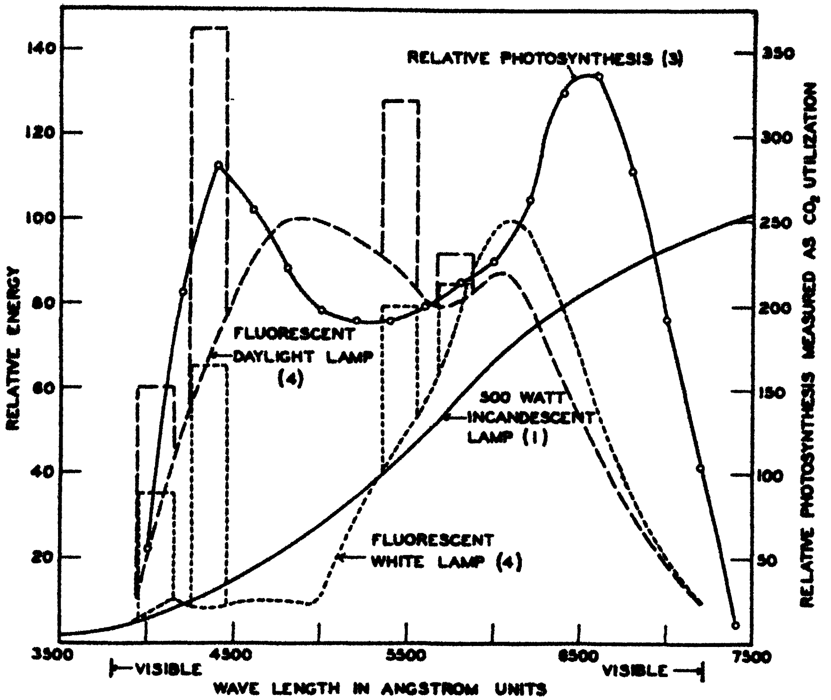


FIG. 5. Comparison of spectal distribution of visible radiation from fluorescent lamps and incandescent lamps with curve of relative photosynthesis (the rectangular blocks represent the energy output of the visible mercury lines emitted by the fluorescent bulbs).

The cabinets are being used at present for a study with strawberry plants but are designed so that larger plants could be used. The strawberries have maintained a growth rate comparable to plants grown in the field in the same soil as shown by measurements given in Table I.

TABLE I—GROWTH MEASUREMENTS OF TWO VARIETIES OF STRAWBERRIES DURING A 14-WEEK PERIOD FROM JULY 9 TO OCTOBER 15, 1942 (AVERAGE OF 10 PLANTS)

Variety	In Environment-Control Cabinets				In Field
	High Temperature (75 Degrees F)		Low Temperature (60 Degrees F)		
	10-hour Day	15-hour Day	10-hour Day	15-hour Day	
	Average Petiole Length During 14-Week Period (Mm)				
Marshall	50	69	47	54	62
Missionary	62	67	52	62	69
	Average Leaf-Product During 14-Week Period* (Sq. Mm)				
Marshall	2312	2948	2495	2947	2936
Missionary	1897	2016	2107	2520	2221

*Length x width of middle leaflet.

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Valid Estimates of Variance in the Analysis of Pooled Data

By E. B. Roessler, *University of California, Davis, Calif.*

THE theory on which the analysis of variance is based assumes that the experimental errors to which the data are subject shall be independently and normally distributed with the same variance. Of these restrictions the last is the most important. Frequently sets of measurements are combined to estimate an experimental error for the pooled data. This procedure is valid if all sets may reasonably be expected to have the same variance, that is if their variances are homogeneous. The original sets then may be considered as random samples drawn from the same population. If the variances are not homogeneous, they may not be considered as belonging to the same population; and, therefore, the pooled or average error is not really applicable to any of the original sets.

Recently experiments have been duplicated at various stations and the results combined to obtain a better estimate of the standard error and one valid for the region of which the stations represent a random sample. In such cases a few investigators have been careful to test the individual station variances for homogeneity; but, unfortunately, several well-known reference books on statistical procedure have combined such data and determined a pooled or average standard error without first justifying the validity of such procedure by testing the homogeneity of the individual variances. It seems, therefore, appropriate to call attention to a proper method of procedure in such cases.

The L-tests of Pearson and Neyman (1) may be applied where tables are available. Bartlett (2) has pointed out that the chi-square distribution can be used as an approximate test of several estimates of variance. The pooled variance v of k estimates of variance $v_1, v_2, v_3 \ldots v_k$ based on $n_1, n_2, n_3 \ldots n_k$ degrees of freedom respectively is their weighted mean, that is

$$v = \frac{\Sigma n_i v_i}{n} \text{ where } n = \Sigma n_i$$

Then the quantity $\frac{2.3026}{C}(n \log_{10} v - \Sigma n_i \log_{10} v_i)$

in which $C = 1 + \frac{1}{3(k-1)}\left(\Sigma \frac{1}{n_i} - \frac{1}{n}\right)$

is approximately distributed as χ^2 with $k - 1$ degrees of freedom, and an unduly large value indicates discrepancies among the several estimates of variance.

If the k variances are each based on the same number of degrees of freedom m, the expression for χ^2 reduces to

$$\chi^2 = \frac{6.9078\ km^2}{3\ km + k + 1}(k \log_{10} v - \Sigma \log_{10} v_i).$$

It can be shown that the first factor of this expression differs from $2.3026\left(m - \frac{1}{3}\right)$ by less than $\frac{0.7675}{k}$ and, therefore, a simplified approximation for χ^2 applicable to most analyses is

$$\chi^2 = 2.3026\left(m - \frac{1}{3}\right)(k \log_{10} v - \Sigma \log_{10} v_i)$$

with $k - 1$ degrees of freedom.

As an illustration the test will be applied to part of the data of the cooperative pea-seed-treatment tests conducted in 1941 under the auspices of the committee for coordination in Cereal and Vegetable Seed Treatment Research of the American Phytopathological Society. The seed protectants, red copper oxide, Semesan, 2 per cent Ceresan, and Spergon, were applied to pea seeds of the Alaska variety. The seeds were then distributed to cooperators in 20 states and two provinces of Canada. Thirty-three sets of uniform seed-treatment tests were conducted at these 22 locations. Each set of seed-treatment tests consisted of five replications of 100 seeds of each treatment and an untreated check. The seedling stands were counted and variance analysis was applied to the data of each test. Treatment differences as well as replication differences were fairly uniform in all the tests and the error variances obtained for the locations appeared to be valid estimates of test variabilities. In Table I are indicated for six of these tests the error variances with the corresponding common logarithms.

TABLE I—ERROR VARIANCES WITH THE CORRESPONDING COMMON LOGARITHMS FOR SIX TESTS

Station	Degrees of Freedom m	Variance v_i	$\log_{10} v_i$
Connecticut	16	48.1	1.6821
Idaho	16	23.5	1.3711
Illinois	16	22.1	1.3444
Oklahoma	16	49.1	1.6911
South Carolina	16	11.8	1.0719
Wisconsin	16	17.4	1.2405
Totals		172.0	8.4011

The average (pooled) variance is 172.0/6 = 28.7, the common logarithm of which is 1.4579.

Then

$$\chi^2 = 2.3026\left(16 - \frac{1}{3}\right)[6(1.4579) - 8.4011]$$
$$= 2.3026\,(15.67)\,(0.3463)$$
$$= 12.5 \text{ with 5 degrees of freedom.}$$

Referring to a table of χ^2 for 5 degrees of freedom we find that $\chi^2 = 11.1$ when $P = 0.05$. We conclude, therefore, that deviations between variances as great as those observed would occur less than five times in 100 trials through errors of random sampling. The six error variances may not be considered homogeneous, and no single estimate of variance is valid for the combined data, which, therefore, cannot be subjected to a single analysis of variance. In such cases an examination of the data may indicate that if certain tests having exceptionally large or small variances are omitted, the remaining tests have variances which are homogeneous; and, therefore, may be combined in a single analysis. If many variances are involved, the testing can be carried out within two or more groups, each group with homogeneous variance.

In all analyses in which variances are to be combined, some such preliminary procedure should be followed in order to insure the validity of the pooled error variance.

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The Coefficient of Contingency for Horticultural Research

By JOHN W. CRIST, *Michigan State College, East Lansing, Mich.*

THE coefficient of contingency, as an expression for correlation between variants, is not a new procedure in the realm of mathematics. It was devised originally by Pearson (5). Its use in certain fields of research, since its introduction, has been somewhat extensive. In horticultural research, however, where its utility might have been high, it has not been taken up and made to serve a purpose. Hence, its presentation here,—as the fifth offering in a series of such presentations which had a beginning in the Proceedings of the Society for the year 1938.

With respect to correlation, this measure has the merit of being applicable in those instances where the data are essentially qualitative in kind, and can be grouped only in broad and mostly indefinite categories. There is also the additional advantage that the gradations of intensity for the attributes of the material under consideration may be several to many in number.

The procedure for the coefficient's derivation consists in estimating the degree of association between the variance of attributes by means of "a function of the difference between the numbers actually found in the cells of a correlation table and the numbers that would be found if the two variables were independent in the probability sense".

A demonstration can be made for the data given in Table I. These data were obtained from the inspection of 3,000 Northern Spy apples, taken from storage a short time after they had been harvested and stored. The two attributes—defectiveness (limb rub, insect stings, and so forth) and color were associatively considered, with each of these two divided into three grades of intensity, to give a table of nine cells.

TABLE I—DATA SECURED FROM INSPECTION OF 3,000 NORTHERN SPY APPLES FOR DEFECTIVENESS AND COLOR

Color	Defectiveness			Totals (f_i)
	Slight	Medium	Great	
High	453	187	160	800
Medium	400	850	250	1500
Poor	140	162	398	700
Totals (f_j)	993	1199	808	3000(N)

The problem is quite simple. It consists in finding the squared difference between the actual number of pairings in each cell and *the number* expected on the basis of pure chance association. This value is then put into the terms of the expected number. Such a value is computed for each cell. These values are then summed together, and the sum divided by the total number of observations. This gives ϕ^2, the mean-square contingency.

Expressed as a formula:

$$\phi^2 = \frac{1}{N}\Sigma \left\{ \frac{\left(Nc - \frac{f_1 f_2}{N}\right)}{\frac{f_1 f_2}{N}} \right\} + \ldots\ldots\ldots\ldots, \text{ the}$$

summation extending to all of the several cells.

For each cell "Nc" is its actual frequency; "f_1" is the total for its row, and "f_2" the total for its column.

For, say, the cell in the upper left-hand corner of the table the calculation is as follows:

$$\phi^2 = \left\{ \frac{\left(453 - \frac{800 \times 993}{3000}\right)^2}{\frac{800 \times 993}{3000}} \right\} = 133.76$$

The sum of these values for the nine cells is 703.07. Therefore, $\phi^2 = \frac{703.07}{3000} = 0.2344 =$ the mean-square contingency.

Then, C_1 (coefficient of contingency) $= \sqrt{\frac{\phi^2}{1 + \phi^2}} = \sqrt{\frac{0.2344}{1.2344}} =$ 0.445.

The indication is that of real but not high correlation between the two attributes—defectiveness and color—for the fruits examined and classified.

The error in such groupings is most likely large. In order to relieve this error, at least in part, Pearson (6) devised a correction for ϕ^2. It is: $\frac{(K - 1)\ (\lambda - 1)}{N}$. K is the number of rows; λ the number of columns.

In this case, the correction becomes: $\frac{(2)\ (2)}{3000} = 0.0013$. Hence, $\phi^2 = .2344 - .0013 = .2331$. This changes the value of C_1 to $\sqrt{\frac{0.2331}{1.2331}}$ $= 0.435$.

Later, Pearson (7) provided a formula for calculation of the probable error of the coefficient of contingency. This need not be discussed and demonstrated. The original article is easily available and readily usable. This error for the case in hand is 0.0039. Probability for the significance of the coefficient (0.435) is very high, since it is more than 100 times its probable error.

The constant need for correlation measures in horticultural research is realized by most of the operators. This need is particularly acute because in this field the instances where only more or less qualitative measurements are possible are still numerous. This being true, it appears that this deficiency may be mostly overcome by turning to utilization of the coefficient of contingency,—together with the other measures of correlation which have been previously presented and demonstrated (1, 2, 3, 4), and which have, each in its way, particular aspects of adaptability and advantage.

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Investigations in Vegetable Dehydration

By W. V. Cruess, *University of California, Berkeley, Calif.*

OWING to the great demand for concentrated foods of all kinds for use by the American armed forces overseas and by our Allies under the Lend-lease program there has developed a tremendous demand for dehydrated vegetables and dried fruits. Consequently, there has been a very great expansion in dehydration of vegetables in the West. There are probably not less than 30 commercial plants in operation in the western states of California, Oregon, Washington, and Idaho. In California, in several cases existing prune or grape dehydraters have been converted for the dehydration of vegetables. In other cases entirely new plants have been built. In California, and to a lesser extent in Washington, several plants have been in operation for a number of years on such specialties as dried onions, garlic, and dried vegetables for pharmaceutical use, and to a lesser extent dehydrated vegetables for campers, Arctic expeditions, and so on.

The dehydration of vegetables for Army use is not new. Dried vegetables were used by the Union forces in the Civil War, by the British in their South African campaign, and by the United States in World War I. However, the dried products in use were not very attractive in flavor or color. They were used to prevent scurvy in the Civil War, but present knowledge would indicate that the dried products were useless to prevent scurvy. During World War I, the American soldiers in France found the dehydrated vegetables, with the possible exception of potatoes very unpalatable and tough. We now know that this inferior quality was due to the failure to blanch the vegetables before drying, and to packing the vegetables in air, rather than in CO_2 or in vacuum. Also the dehydrated vegetables of World War I were too high in moisture content. These three conditions account for the rapid deterioration.

Raw Materials

One difficulty in California has been to procure enough fresh vegetables for dehydration to supply the armed forces and the lend-lease program. Most of the expansion has taken place since Pearl Harbor, and during this period there has not been time to grow sufficient additional crops of potatoes, carrots, and so on for dehydration. The great influx of defense workers has made great inroads on the supply and consequently has made it difficult for the dehydraters to get the raw materials. At this date some of the dehydraters have not sufficient vegetables for dehydration, and are still competing with each other and with the fresh market for the supply of raw material. It is obvious that the dehydrater should plan well in advance for the entire season. Some of the more experienced operators have done this. Some have been forced to use cull potatoes, for example, which gave undesirable results. The variety is very important. Among western potatoes, the Netted Gem variety is considered best of the commercial varieties. The White Rose has given good results in experimental dehydration.

Among cabbage varieties the Savoy is considered best, but there is very little of it, as the yield per acre is low, and there is less produced than of the solid Dutch and Danish types. The latter types have been accepted for general use, as they are the ones available.

Among the onion varieties, the Louisiana Creole and Ebenezer are considered best because of their high pungency and drying yield. The White Globe is also considered good for dehydration.

Of the commercial varieties of carrots, we have found that the Imperator and the Chantenay are about the best under California conditions. We have tested these in cooperation with the Truck Crops Department. However, the Nantes variety also gives good results.

In our tests some 15 varieties of string beans were compared. It was found under our western conditions that the Blue Lake and Kentucky Wonder, and other pole varieties give better results than the bush varieties of string or stringless beans.

We have made no comparison of pea varieties. However, from experience with different pea varieties for frozen pack, it is likely that the Alderman and simliar types would be satisfactory.

Dr. J. S. Caldwell, of the United States Department of Agriculture, at Beltsville, Maryland, has made a very extensive study of corn varieties for dehydration. He and Dr. C. A. Magoon, of the same laboratory have made thorough comparisons of the different varieties of sweet potatoes for dehydration. It may be said that different vegetables vary greatly in their suitability for dehydration, so that they give products of good color, flavor and odor if stored.

Asparagus, in our experiments, has failed to respond well to dehydration. The same is partially true of the globe artichoke. All other vegetables that we have tested have given satisfactory results. An excellent vegetable for dehydration is broccoli. Brussels sprouts respond very well to dehydration. However, there is still a great deal of work to be done on comparison of varieties, and on the effect of climatic and cultural conditions to produce vegetables suitable for dehydration.

In California, the Santa Clara Canner, a variety of the beefsteak tomato and the San Marzano, a small pear shaped Italian variety, have been used very satisfactorily for preparing dehydrated tomato cocktail. In the eastern states, the Stone variety has proved very successful for dried tomato soup and cocktail. For these products, the tomato should have high color and pronounced flavor. For drying in slices or halves or quarters, we find the Santa Clara and San Marzano both very satisfactory.

CANNER INTEREST IN DEHYDRATION

There is a great shortage of tin for packing in cans. A number of products are no longer canned, such for example as beer, dog food, and pork and beans. Unless the American Navy recovers the Malay States and the Dutch East Indies soon, it is likely that the limited tin supply will dwindle rapidly, and that several other items will be put on the prohibited list. In that case it is likely that such vegetables as corn, carrots and peas will be dehydrated. Canners are aware of this possibility. Therefore all large canning companies are thoroughly investigating dehydration. Several companies have already built large dehydraters. Among these are the Beechnut Packing Company of Rochester, New York and the Heinz Company of Pittsburgh.

For the duration of the war, there is no reason why the housewife can not use satisfactorily such dehydrated vegetables as peas, corn, string beans, pumpkin, and powdered tomatoes. Dried soups are already on the market.

FRESHNESS

Dr. E. M. Chace and his associates of the United States Department of Agriculture have shown that some fresh vegetables show a rapid loss of vitamin C after they have been picked. This is especially true of the leafy vegetables. Consequently vegetables should be garden fresh when used for dehydration. Of course, potatoes and onions can be stored for considerable periods before dehydration, but are best if stored only a short time.

BLANCHING EXPERIMENTS

In World War I, potatoes were scalded or blanched in boiling water for sufficient time to cook them, and destroy the enzymes. Other vegetables should be similarly treated, but the commercial firms were not in a position to treat them, or thought it unnecessary. Experiments by the United States Department of Agriculture and by the Fruit Products Division of the University of California have demonstrated during the past few years that most vegetables should be blanched before dehydrating, and that blanching in steam is superior to boiling water; because blanching in water leaches large amounts of sugar, minerals and vitamins. We have found that blanching should be sufficiently long to destroy all enzyme activity. A convenient test for thoroughness of blanching is the peroxidase test. One method of making this test is to place 2 or 3 grams of crushed sample in about 10 cubic centimeters of water and add a few drops of guaiacol in 50 per cent alcohol, and a few drops of 1 per cent hydrogen peroxide. A reddish coloration of the sample and liquid is positive indication of peroxidase activity. If there is a vigorous evolution of oxygen (gas) from the sample on the addition of hydrogen peroxide this indicates a positive test for catalase. Catalase is destroyed at a lower temperature than is peroxidase. We find that dehydrated vegetables showing a positive peroxidase test and negative catalase test do not stand up well in storage. Both enzymes should be destroyed. While it is possible that these enzymes are not the only ones involved in destructive changes in flavor, color and odor, they may be tested easily and therefore act as indicators for all enzymes. Early in our experiments we found that most vegetables can be completely pre-cooked before dehydration, then the dehydrated product refreshes quickly in water, and cooks very quickly, in some cases even more rapidly than fresh. Potatoes should not be completely cooked unless they are to be riced because completely cooked potatoes become mealy and crumbly. Mrs. Hazel F. Friar, the Fruit Products Division, University of California, finds that pre-cooking under steam pressure gives excellent results and the dehydrated products can be very rapidly rehydrated.

DRYING TEMPERATURE

While vegetables are high in moisture during the initial stages of drying, they will stand high temperature without scorching or other damage. For example, spinach will stand air at 300 degrees F during the first stages of drying, on the other hand most vegetables are very sensitive to heat when they are dry or nearly dry. For example at 145 degrees F onions, potatoes and beans very rapidly "burn", that is scorch and darken, when nearly dry. Carrots on the other hand, will stand 160 degrees F when nearly dry. Because of possible injury near the end of the drying period some dehydraters place the dehydrated product in bins and finish the drying process at 110 to 125 degrees F. This procedure not only protects the product, but also increases the capacity of the dehydrater.

TYPES OF DEHYDRATERS

The most common vegetable dehydrater in California is that known as the Counter Current Forced Draft Tunnel Dehydrater. It usually consists of a tunnel about 6½ feet wide, 7 feet high and 50 to 60 feet in length. Beside it is another tunnel of similar size which has the air heating system and fan. The second tunnel also acts as a return duct for some of the spent air. If natural gas is used the products of combustion pass over the product with sufficient air to decrease the temperature to the desired point. The blanched vegetables are placed on wooden trays and the trays in turn are placed on low trucks or cars. The trays are usually 6 by 3 feet in size and about 30 trays are placed on each truck. From 6 to 12 trucks are placed in the tunnel. The fresh material is placed in the cool end of the tunnel and travels progressively toward the warm end, where drying is completed. The temperature varies from 120 degrees F at the cool end to 140 to 150 degrees F at the hot end. In the so called Canadian system, however, the first part of the drying period is by the parallel system by which the product enters the hot end and proceds toward the cool end. A very high initial temperature is used, perhaps 190 degrees F. The product is partially dried in this first tunnel and it is then placed in a second tunnel where it then travels counter current to the hot end where drying is finished at 140 degrees F.

Recently C. C. Eidt of Canada combined the two tunnels into one. In this case there are two separate fans and two separate heating systems and the air is blown from each end toward the center of the tunnel. At that location is a door or partition which separates the two sections. One of these driers has been built by the Beechnut Company in Rochester, New York and another by the Heinz Company of Pittsburgh.

DEHYDRATION AND REFRESHING RATIOS

The Army and various other investigators, as well as our own laboratory, have found that dehydrated vegetables do not recover in cooking all of the weight lost in dehydration; 10 pounds of fresh carrots give 1 pound dried, but 1 pound of dried gives only 6½ pounds of cooked carrots after dehydration. In one test, spinach gave a drying ratio of 10:1 and a cooking ratio of 5.7:1. For cabbage the drying ratio was 15:1 and the cooking ratio 9:1. For potatoes the case is somewhat better, as the drying ratio was about 5:1, and 1 pound of the dried potatoes gave 4½ pounds cooked. Tomatoes gave about the same ratio as cabbage and onions about the same ratio as carrots in some cases although in other cases the onion attained a somewhat higher weight than did the carrots. Of course, there is a somewhat similar decrease in the cooking of fresh vegetables, although the difference is not so great as with the dehydrated products.

VITAMIN LOSSES

Research by various laboratories has shown that loss of vitamin C in the dehydration of most vegetables is very serious. In the unblanched it is often 100 per cent within a few weeks after drying is completed. Blanching before drying retards the loss of vitamin C, and if the vegetables are lightly sulfured with SO_2, or wet with bisulfite, vitamin C will be retained, but B_1 is injured by the SO_2.

The work of Mackinney, of this laboratory shows that carotene is well retained by blanched vegetables in dehydration, but in carrots particularly it rapidly disappears from the dried product if stored in air. If stored in vacuum or inert gas it is well retained.

The research of Sugihara and Mackinney, of this laboratory, as well as by the Home Economics Department of this University, and various United States Department of Agriculture research laboratories indicates that the vitamins of the B complex are quite stable to drying and are fairly well retained in storage.

MOISTURE CONTENT

In World War I, the maximum (limit) of moisture content was about 10 per cent. We now know that this was altogether too high because at 10 per cent moisture content dried vegetables rapidly deteriorate in flavor, color, and odor. Army specifications now call for moisture content below 5 per cent, except for potatoes which may be 7 per cent and cabbage and onions 4 per cent. At these low moisture contents deterioration is greatly retarded. The Army specifications make it essential that the dehydrater have a laboratory and a chemist to make frequent moisture determinations. He is also useful in testing for enzyme activity.

THE FUTURE

Dehydration enthusiasts are making rather wild predictions as to the possible expansion of dehydration during and after the War, particularly after the War. Judging by our experience after World War I, and the recent phenomenal increase in frozen pack, our guess would be that the dehydration of vegetables for the civilian population will not increase to the extent visualized by the advocates of dehydration. However, we might expect that such products as riced dehydrated, mashed potatoes, dehydrated shoe string potatoes, dehydrated onions, peas and corn, as well as certain soup vegetables may become more popular than at present.

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Vegetable Rotation Studies, I[1]

By M. L. ODLAND and A. M. PORTER, *University of Connecticut, Storrs, Conn.*

IN 1939 an experiment was designed to study the feasibility of several rotations for vegetable production. Invariably, the crops of onions in the rotations have been infested with pink root disease which, apparently, influenced the yield. There appeared to be an association between the amount of disease and the type of crop preceding in the rotation. In 1942, in the same series of rotations, the tomato crops were infested with wire worms. The worms attacked the plants about the time of the first fruit set. At that time there appeared to be considerable variation in the amount of damage relative to the different rotations. Data were obtained in an attempt to evaluate the damage resulting from the presence of pink root and wire worms, as well as to evaluate the direct rotational effect.

THE ROTATIONS AND METHOD OF OBTAINING THE EXPERIMENTAL DATA

The rotations considered in this paper are four, 4-year rotations of different levels of intensity of cropping. The schematic set up is as follows:

Rotation	First Year	Second Year	Third Year	Fourth Year
e	Carrots-spinach*	Tomatoes (rye)	Spinach-beets	Onions (rye)
f	Carrots-spinach	Tomatoes (rye)	Spinach-beets	Onions (rye)
g	Sweet corn (vetch)	Tomatoes (rye)	Peppers (rye)	Onions (rye)
h	Soybeans (rye)	Tomatoes (rye)	Sweet corn (vetch)	Onions (rye)

*Manured.

This arrangement, which is randomized, is replicated four times, thus providing four replications of each rotation, with each crop represented each year. The crops of tomatoes and onions in alternate years provide a means of measuring differences in rotational effects, and are similarly planted in grouped plots.

The fertilizer treatment is as follows: All early crops (carrots and spinach), except carrots in rotation "e", received an application equivalent to 1500 pounds of 5–10–5 per acre. The carrots in rotation "e" received 1200 pounds of 4–12–4 per acre, and this rotation is also influenced by an application of manure at the rate of 16 tons per acre. The all-season crops (sweet corn, peppers, tomatoes and onions) were treated with an equivalent of 1500 pounds of 4–12–4 per acre while the fall crops (spinach and beets) received an application at the rate of 1200 pounds of 7–7–7 per acre. The pH had, by controlled application of lime, been brought to approximately 6.5 on all plots. The green manure crop, soybeans, was plowed under when maximum growth had been obtained. The rye and vetch cover crops were plowed under sometime before spring planting.

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[1] Methods of statistical analysis used were suggested by Dr. C. I. Bliss, Station statistician.

In 1941 and 1942 an inspection of the onion crops during the growing season showed that pink root disease was very prevalent, especially so in the crop following sweet corn. At harvest time the bulbs were sorted into three classes—(a) the marketable, which in general were good sized solid bulbs and showed little or no symptoms of disease; (b) the second sized bulbs, which in almost every instance showed symptoms of disease; and (c) the decayed bulbs, which apparently were decayed primarily as a result of disease. Inasmuch as the first class was almost free of disease and the latter two classes were nearly 100 per cent diseased, it appeared that the per cent of unmarketable, that is diseased, bulbs would give a measure of disease damage. It should be pointed out that this measure is not infallible, but it was the only measure available.

In 1942 a severe infestation of wire worms appeared in the tomato plots early in the season. Damage was extensive, and appeared to be most severe in the crops following sweet corn and vetch and following soybeans and rye. At the time of the last harvest the percentage of injured roots was recorded as a measure of injury.

Analysis of Experimental Data and Discussion

Onions:—In Table I it may be noted that considerable variation was found in number of marketable bulbs, in disease injury and in marketable yield in weight, in both 1941 and 1942. In Table II the analysis of variance and covariance is presented. It should be pointed

TABLE I—Number of Marketable Bulbs, Disease Injury and Yield of Onions for Two Seasons; and Number of Plants, Wire Worm Injury and Yield of Tomatoes for One Season

Rotation	Tomatoes			
	Crop Preceding	Average Number of Plants Per Plot	Average Yield Per Plot (Lbs)	Per Cent Worm Injury
e*	Carrots† Spinach‡	32.0	279	84
f	Carrots† Spinach‡	32.0	244	91
g	Sweet Corn (vetch)	30.0	115	80
h	Soybeans (rye)	29.8	126	97

Rotation	Onions						
		1941			1942		
	Crop Preceding	Average Number Bulbs Per Plot	Per Cent Disease Injury	Average Yield Bulbs Per Plot (Lbs)	Average Number Bulbs Per Plot	Per Cent Disease Injury	Average Yield Bulbs Per Plot
e*	Spinach† Beets‡	852.5	23	140.0	1010.2	22	188.0
f	Spinach† Beets‡	801.7	26	135.2	872.5	20	162.0
g	Peppers (rye)	883.0	17	169.2	1229.5	8	283.7
h	Sweet corn (vetch)	475.0	44	72.0	381.2	64	61.2

*First year of rotation "e" treated with application of manure.
†Early crop.
‡Late crop.

out that stand was uniform on all plots before thinning time and apparently so for some considerable time after, or until the disease began to appear.

TABLE II—ANALYSIS OF VARIANCE AND COVARIANCE FOR NUMBER OF BULBS, DISEASE INJURY, AND YIELD IN THE ONION CROPS IN 1941 AND 1942

Variation Due To	D.F	Number Marketable		Disease Injury		Yield (Lbs)		D.F.	Yield (Lbs) After Taking Out Effect of Disease	
		M.S.	F.	M.S.	F.	M.S.	F.		Re-duced M.S.	F.
				1941						
Blocks	3	36870	14.6†	38.8	1.8	1517.0	9.1†	3	105.55	——
Effect of sweet corn	1	413109	164.2†	533.3	24.5†	17404.0	103.9†	1	3807.94	21.4†
Peppers versus spinach-beets .	1	8177	3.3	80.7	3.7	2667.0	15.9†	1	1576.67	8.6*
Manure on spinach-beets . .	1	4950	2.0	12.5	0.6	45.0	0.3	1	23.11	0.1
Error .	9	2516	——	21.78	——	167.5	——	8	182.34	——
Blocks . . .	3	34038	0.6	169.8	2.2	2222.0	1.1	3	2173.43	——
Effect of sweet corn	1	1324681	21.8†	3366.8	43.4†	67500.0	33.9†	1	68.78	0.3
Peppers versus spinach-beets.	1	202584	3.3	315.4	4.1	31357.0	15.8†	1	5829.76	27.2†
Manure on spinach-beets. .	1	52975	0.9	0.1	0.0	1352.0	0.7	1	1480.07	6.9
Error	9	60750	——	77.58	——	1993.0	——	8	214.58	——

*Significant.
†Highly significant.

A very significantly smaller number of marketable bulbs were produced on the plots following sweet corn (rotation "h"). The differences in number of bulbs in the other rotations (e, f, and g) are not significant.

In the analysis of percentage of disease free bulbs, the percentages were converted to angles as suggested by Bliss. The fact that variation in disease between blocks is not significant shows that prevalence of disease was neither associated with soil type nor localized in any particular place in the field. A very significantly greater disease injury is found in rotation "h", where sweet corn precedes the onion crop. Field observations indicated that there was less disease in onions following peppers as compared with onions following spinach and beets. The analysis shows the difference to lack somewhat of being significant. There was no difference in prevalence of disease in rotations "e" and "f", that is, the manurial treatment did not effect the amount of disease.

In Table II it may be noted that yield (weight) of the crop of onions following sweet corn was very significantly smaller than the yield of the onion crops in the other rotations during both of the seasons. However, when the effect of disease is eliminated, the F value in 1941 is reduced from 103.9 to 21.4; while in 1942 the F value is reduced from 33.9 to a value that is not significant. Although it was pointed out that the measure of disease injury used is not infallible, the results might be interpreted as showing that disease is the primary cause of the poor yield in rotation "h". Table I shows that sweet corn preceded the onions in this rotation and that a green manure was plowed under in the third year preceding. It would seem that the immediately preceding crop might be the more important factor. The onion crops in rotations "g" and "h" were similarly treated insofar as they were preceded by an all-season crop followed with a winter cover and received identical fertilized treatment. Although, with the removal of the stalks, the corn crop removes somewhat more fertility from the soil than do the peppers, this factor would not appear to account for the great difference in yield, and consequently we might conclude that prevalence of disease after corn is a factor of prime importance. Onions following peppers produced a very significantly greater yield than onions following spinach and beets. In 1941 when the variances for yield are reduced, eliminating the effect of disease, it is found that, although the crop following peppers yields significantly greater than the crops in the rotations following spinach-beets, the difference is not as great as when actual yields are considered. In 1942 when the variances of yield are reduced the F value obtained indicates that yield differences between the two types of rotations are even more pronounced than when actual yields are considered. It would seem that the onion crop in the rotation following peppers outyields the crops in the rotations following spinach and beets and would likewise produce better if disease were not present. Considering the onion crops in manurial treated versus the non-manurial treated rotation, it may be noted that in 1941 yield and disease prevalence differences were not significant. In 1942, however, the F value 6.9 indicates that, when the effect of disease is eliminated and treatment effect only is considered, the manured plots yielded significantly more than the unmanured plots.

Tomatoes:—The data obtained on tomatoes are presented in Table I. The analysis of variance showed no significant variation between rotations in per cent of wire worm injury. However, inspection of the plants at last harvest proved a rather unsatisfactory method of evaluating worm injury as it appeared that the plants had taken root again even after rather severe injury. It may be noted that survival of plants is slightly better in tomatoes following carrots and spinach, however, this difference does not prove to be significant.

Early season observations suggested that the extent of injury was such that some of the plants would be killed off especially in the "g" and "h" rotations. The yields following sweet corn and following soybeans were significantly lower than after carrots and spinach. It may be noted that in these cases cover crops were started in the fall and plowed under in the spring. This is an instance where a green manure crop and cover crops do not appear especially beneficial. Of course less fertilizer is applied to these two rotations than to the other two and this may be a partial explanation of the results. The elimination of manure on the carrot crop with a supplement of commercial fertilizer caused only a slight falling off in yield of the following crop of tomatoes.

Effect of Different Soil Treatments on Available Moisture Capacity of a Vegetable Soil

By LEON HAVIS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

THE purpose of this study was to determine the relationship between the organic matter content and the available moisture under the conditions at Marietta, Ohio, where large amounts of organic matter had been added to certain vegetable plots for 27 years. In other plots no organic matter except that produced by the cover crops and the crop residues had been added during that length of time. Horticulturists are principally concerned with the value of organic matter in the form in which it is present in the soil complex following long periods under different cultural systems. A detailed soil survey map of the experimental plots, a description of the treatments, and other information on these plots are given in a recent bulletin by Bushnell (4).

The available soil moisture (or potential available moisture) content is usually considered as the difference between the field capacity, or the moisture equivalent, and the wilting percentage. Some of the more pertinent work on this subject has been reviewed briefly by the writer (5). In a previous study of the Marietta soils (6), it was found that there was a significant difference in organic matter between the manured and check plots, but that the differences were not great, and that in all plots the total amount of soil organic matter was low.

MATERIALS AND METHODS

The soils used in these studies were obtained from the Marietta Truck Station in Southeastern Ohio during June 1940 and 1941. The samples were taken to a depth of 5 inches at 14 positions systematically distributed over each plot for wilting percentage and moisture equivalent determinations. The soil types used were Chenango loam and Chenango fine sandy loam. These are terrace or second bottom soils of the Muskingum River. The surface soil is brown, the subsoil is yellowish brown; the drainage is good. Crops of tomatoes, cabbage, cucumbers, and sweet corn are grown in each plot in a 4-year rotation. In addition to the treatments described in Table I, cover crops of soybeans are grown in plots 2, 3, and 5 after the cabbage crop and with the tomatoes and sweet corn following the last cultivation. Rye is sown in all the plots in the fall and plowed under in the late fall or winter. The manure was added during the late winter or early spring of each year.

The organic matter determinations were made on samples ground in a ball mill and passed through a 100 mesh sieve. The chromic acid (1, 7) method of organic matter determination was used.

The wilting percentage was found by use of dwarf sunflowers, in general, following the method originally suggested by Briggs and Shantz (3). The moisture equivalent was determined by use of the centrifuge (2). Since it has been shown (8) that the moisture equiva-

TABLE I—Fertilizer and Organic Matter Treatments of Vegetable Plots Used in the Organic Matter and Moisture Studies

Plot Number	Treatment (Per Acre)
	Chenango Loam Soil
2	1915–22—16 tons manure, 400 pounds superphosphate 1923–30—16 tons manure, 800 pounds superphosphate 1931–42—8 tons manure, 1,000 pounds 0–8–0
3	1915–30—16 tons manure 1931–42—8 tons manure, 1,000 pounds 8–8–0
4	1915–30—No treatment 1931–42—1,000 pounds 8–12–8
5	1915–22—16 tons manure 1923–30—20 tons manure 1931–42—16 tons manure, 1,000 pounds 8–8–0
22	1915–30—No treatment 1931–42—1,000 pounds 8–12–8
	Chenango Fine Sandy Loam Soil
28	1915–30—16 tons manure, 400 pounds superphosphate, 1 ton lime 1931–42—16 tons manure, 1,000 pounds 8–6–4
29	1915–30—No treatment 1931–42—1,000 pounds 8–12–8
33	1915–30—1 ton lime 1931–42—No treatment

lent is not a good measure of the field capacity of all soils, direct determinations of field capacity were made by means of cylinders placed in the soil at several positions in each plot studied. The 6-inch galvanized iron cylinder was placed around a column of soil to a depth of 10 inches. The soil in the cylinders was then brought to the maximum moisture capacity, and the top of the cylinder fitted closely with moisture-proof material. The soil moisture content after appreciable decrease had ceased was considered as the field capacity. This period was reached within 4 to 6 days. Determinations of percentage moisture at field capacity in the cylinders were then compared with the moisture equivalent of the soil from the same cylinders. It was found that the moisture equivalent was a good measure of the field capacity in the Chenango loam, but that the field capacity was higher than the moisture equivalent in the Chenango fine sandy loam.

At least 10 determinations were run for each mean moisture equivalent and wilting percentage presented. The available moisture was obtained by subtracting the wilting percentages from the moisture equivalents, and determining the standard error of each difference (Table II). The difference between each available moisture percentage and all other available moisture percentages in that soil type was then calculated with the standard error of each difference. The significance of these differences was then determined (Table III).

RESULTS

Organic Matter:—The total soil organic matter was higher in all plots treated with barnyard manure, whether 8 or 15 tons per acre were applied, than the unmanured plots. The differences were not always in direct proportion to the amount of manure added, however. All plots, regardless of treatment, were relatively low in organic matter at the end of this 27-year period. In most cases there is more

TABLE II—THE ORGANIC MATTER AND AVAILABLE MOISTURE IN CHENANGO LOAM AND CHENANGO FINE SANDY LOAM UNDER DIFFERENT SOIL TREATMENTS (BASED ON DRY WEIGHT OF THE SOIL)

Soil and Plot	Organic Matter (Per Cent)	Moisture Equivalent (Per Cent)	Field Capacity (Per Cent)	Wilting Percentage	Available Moisture (Per Cent) (Based on Moisture Equivalent)	Available Moisture (Per Cent) (Based on Field Capacity)
			Chenango Loam—1940			
2	2.69	21.22 ±0.16	22.4	5.99 ±0.09	15.23 ±0.18	16.4
22	2.34	20.03 ±0.18	21.5	5.25 ±0.12	14.78 ±0.22	16.2
			Chenango Fine Sandy Loam—1940			
28	2.40	19.23 ±0.13	20.9	4.83 ±0.13	14.40 ±0.19	16.1
33	1.55	14.41 ±0.12	17.5	4.11 ±0.10	10.30 ±0.16	13.4
			Chenango Loam—1941			
2	2.70	22.16 ±0.13	23.8	5.61 ±0.12	16.55 ±0.18	18.2
3	2.67	22.27 ±0.20	23.3	5.93 ±0.13	16.34 ±0.24	17.4
4	2.26	21.53 ±0.18	22.3	5.79 ±0.09	15.74 ±0.20	16.5
5	2.78	22.59 ±0.14	23.5	5.72 ±0.11	16.87 ±0.18	17.8
22	2.20	21.22 ±0.18	21.3	5.23 ±0.14	15.99 ±0.23	16.1
			Chenango Fine Sandy Loam—1941			
28	2.25	18.68 ±0.19	20.0	5.18 ±0.16	13.68 ±0.25	14.8
29	1.63	14.78 ±0.13	16.8	4.17 ±0.18	10.61 ±0.22	12.6
33	1.46	14.36 ±0.12	16.6	4.18 ±0.12	10.18 ±0.17	12.4

TABLE III—SIGNIFICANCE OF DIFFERENCES IN AVAILABLE MOISTURE BETWEEN PLOTS WHICH VARY IN SOIL TREATMENT (BASED ON DRY WEIGHT OF THE SOIL)

Plots Compared	Difference in Available Moisture* (Per Cent)	Number of Chances to One That the Difference is Not Real
	Season of 1940	
Chenango loam		
2 and 22	0.45 ±0.28	9
Chenango fine sandy loam		
28 and 33	4.10 ±0.25	Over 1000
	Season of 1941	
Chenango loam		
2 and 4	0.81 ±0.27	370
2 and 5	0.32 ±0.25	5
2 and 22	0.56 ±0.29	19
3 and 4	0.60 ±0.31	18
3 and 5	0.53 ±0.30	13
3 and 22	0.35 ±0.33	3
4 and 5	1.13 ±0.27	Over 1000
5 and 22	0.88 ±0.29	410
Chenango fine sandy loam		
28 and 29	3.07 ±0.34	Over 1000
28 and 33	3.50 ±0.30	Over 1000

*Calculated as difference between moisture equivalent and wilting percentage.

difference in organic matter content between the manured and unmanured treatments in the Chenango fine sandy loam than in the Chenango loam. It should be emphasized that these differences resulting from the treatments were not necessarily due to *increases* in organic matter caused by the manure, but probably more to the *maintenance* of it. It may be concluded from these data that large amounts of organic matter added to these soils over a period of 27 years had not brought about a high soil organic matter content, nor great differences between the treated and untreated plots. The differences obtained were significant, however.

Moisture Equivalent and Field Capacity:—The moisture equivalent results were directly related to the organic matter content in most cases (Table II), but the differences were small and in the Chenango loam were in most cases lacking in significance. The moisture equivalent was evidently too low to be used as a measure of the upper limit of available moisture in the Chenango fine sandy loam since it was considerably below the field capacity here (Table II). In most cases the moisture equivalent values were slightly lower in 1940 than in 1941, but there is no evident reason for this.

The results of the determinations show that the field capacity was, during both years and in both types of soil studied, higher than the moisture equivalents. The differences were not great in the Chenango loam, but were more striking in the Chenango fine sandy loam (Table II). There is so little difference in results with the Chenango loam that either method might be used satisfactorily, but the field capacity data are more accurate for the Chenango fine sandy loam.

The difference between the moisture equivalent determinations in the manured (plot 2) and the unmanured plot (plot 22) for 1940 is evidently significant. There is much greater difference, however, between the manured (plot 28) and the unmanured (plot 33) plots in the fine sandy loam during this year (Table II). In 1941 the plots, 4 and 22, which had not been manured were definitely lower both in moisture equivalent and in the direct field capacity measurements than the manured plots, plots 2, 3, and 5 (Table II). Plot 5 was only slightly higher in moisture equivalent than 2 and 3, although it had received the largest amount of manure. There is considerable difference between the manured (plot 28) and the unmanured plots (plots 29 and 33) in the fine sandy loam, whether the moisture equivalent or the field capacity determinations are considered.

Wilting Percentage:—The wilting percentage varied directly with the organic matter, the moisture equivalent, and the field capacity (Table II). Here also the greatest differences between treatments were found in the Chenango fine sandy loam. Even the manured plot in the fine sandy loam had a lower wilting percentage than the unmanured plots in the Chenango loam. Thus the differences in wilting percentage between the two types of soil were greater than between organic matter treatments in the same type.

Available Moisture:—The available moisture was determined by calculating the difference between the moisture equivalent or the field capacity and the wilting percentage (Table II). When the available moisture in the Chenango loam is based on the moisture equivalent, which evidently is permissible because there is little difference between that and the determined field capacity, the differences between the two plots used in 1940 are not shown to be significant (Table III). Thus the addition of 16 tons per acre of manure for 15 years followed by 8 tons per acre for 11 years has, according to this method of determination, failed to bring about a significant difference in available moisture capacity of this Chenango loam soil. In the Chenango fine sandy loam, however, the treated plot, 28, contained approximately 4.10 per cent more available moisture than the untreated ones, 33, in 1940.

The results of available moisture in 1941 were very similar to those of 1940. In the Chenango loam soil, for example, few of the different organic matter treatments showed significant differences in available moisture (Table II). In these few pairs which were significant the differences were not great. In the Chenango fine sandy loam the difference in available moisture (based on moisture equivalent) between plot 28 and 29 and also between plot 28 and 33 were much greater than between similarly treated plots in the Chenango loam, and both were highly significant (Table III).

When the available moisture was based on the directly determined field capacity it was very nearly the same in all plots for the Chenango loam, but in the fine sandy loam the differences were much greater (Table II).

SUMMARY

From these studies it was found that the difference in soil organic matter brought about by additions of manure up to 16 tons per acre over a 27-year period resulted in very little increase in available moisture in the Chenango loam. In most cases the differences in available moisture between the manured and unmanured plots failed to show any statistical significance for this soil. In the Chenango fine sandy loam, there was a significant increase in the percentage of available water in the manure plots.

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Peat as a Soil Supplement in Vegetable Production
A Preliminary Report[1]

By A. E. HUTCHINS and F. A. KRANTZ, *University of Minnesota, St. Paul, Minn.*

THE possible use of peat as a soil supplement is of interest in vegetable production because the intensive cultural methods involved often make the maintenance of an adequate supply of organic matter in mineral soils a difficult problem. Fertility usually can be maintained easily and at relatively low price through the use of commercial fertilizers but depleted humus must be replenished through the addition of organic material.

In an attempt to determine the practicability of the use of peat for this purpose, investigations were begun in 1931 at University Farm and are still being continued. This paper presents some of the results obtained from 1931 to 1941, inclusive.

MATERIALS AND METHODS

A plot of coarse sandy soil, 34 feet wide and 258 feet long was selected for the experiment. This was divided into four equal sections and each section again divided into three plots. Every spring, except in 1940, one plot in each section was given manure at the rate of 20 tons per acre; one finely pulverized peat at the rate of 20 tons per acre; and one was given no organic material. This then gave three treatments in each section and four repetitions of each. In 1940, no peat or manure was added to the plots. To determine the effect of these treatments on the organic content of the soil, tests were made in the fall of 1942. The results of these tests are presented in Table I.

TABLE I—THE PERCENTAGE OF ORGANIC CARBON AND THE pH VALUES IN SOILS UNDER THE DIFFERENT TREATMENTS FOR TWELVE YEARS*

Treatment	Organic Carbon§ (Per Cent)	pH†
Peat	1.47	6.65
Check‡	0.87	6.41
Manure	1.13	6.74

*Data supplied by R. E. Nylund, Division of Horticulture, University of Minnesota.
†Determined with a Leeds-Northrup pH-meter.
‡No organic matter added.
§Determined by a modification of the Furnace Combustion method described in the A.O.A.C. manual.

To determine the effects of these treatments on crop growth, cabbage was grown as a test crop in 1931, 1932, and 1933. From 1934 to 1941 inclusive an early crop of potatoes and a late crop of beets have been grown as test crops each year.

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In 1935, one-half the area used previously was lost through road construction. On the remainder, the same treatments were continued. With potatoes, four replications were continued as previously but the size of block within each treatment was reduced. With beets, the size of block within each treatment remained the same but the number of replications was reduced to two. In 1935, commercial fertilizer was added to certain of the plots and this has been continued each year since. Commercial fertilizers were added to the check plots in such amounts as to give them approximately the same amounts of nitrogen, phosphorus, and potash as would be supplied to the manure plots by the manure. Up to and including 1939, all the nitrogen was applied before planting the potatoes. Since 1939, the nitrogen has been applied, one-half to the potato crop and one-half to the beet crop. The same amounts of phosphorus and potash were applied to the peat plots but no nitrogen was given to them.

Results

In 1931 Danish Ballhead cabbage was grown as a test crop in the experiment. The cabbage plants were started in the greenhouse and transplanted to the field to stand 36 by 24 inches apart. Table II presents the summarized yields obtained.

TABLE II—Yield of Danish Ballhead Cabbage for Each Treatment (1931)

Treatment	Total Number Heads	Weight (Pounds)		Calculated Yield Per Acre (Tons)†
		Total	Average Per Head	
Peat	262	664	2.53	9.18
Manure	292	765	2.62	9.51
Check*	287	729	2.54	9.22
Average			2.56	9.29

*No organic matter added.
†Assuming a perfect stand.

From the data given in Table II it can be seen that there was very little difference in yield between the three treatments, the manure plot producing only 660 pounds more than the lowest yielding treatment. The check and peat plots showed almost identical yields. This was to be expected since the land had been well-manured and had had rye plowed under for many years. It will be noted also that the average weight per head was low in all plots. This was probably due to the very dry conditions prevailing during the growing season.

In 1932, Danish Ballhead cabbage was again used as a test crop but no data were obtained. Cabbage "wilt" or "yellows" made its first appearance and very few plants survived to form heads.

In 1933, a wilt resistant variety of the Hollander type was used. However, this also proved unsatisfactory for testing the soil treatments. The growing season was very hot and dry and about 60 per cent of the plants of the resistant variety were either killed or badly stunted by the wilt. Three hundred plants of the Danish Ballhead variety used to check on the disease were killed without any of them reaching the heading stage.

In 1934, and thereafter, an early crop of potatoes, planted about April 15 and harvested about July 15, followed by a late crop of beets were used as test crops. The average yields of potatoes obtained with the different treatments from 1934 to 1941 inclusive are presented in Table III.

TABLE III—AVERAGE YIELD OF POTATOES FOR EACH TREATMENT (1934 TO 1941 INCLUSIVE)

Treatment	Yield (Bushels Per Acre)		
	Total	Marketable	Culls
Peat	192	134	58
Check*	218	155	63
Manure	195	134	61
Significant difference 5 per cent point	7.2	6.8	3.6
Significant difference 1 per cent point	10.8	10.3	5.4

*No organic matter added.

The data presented in Table III indicate that there was no significant difference in total, marketable or cull yields between the peat and manure treatments. It is interesting to note that the check plots which had received no organic material since 1930, produced a significantly higher total and marketable yield than either the peat or manure treatments. This may be because the nitrogen in the mineral fertilizer applied to the check plots was more readily available than the organic nitrogen of the manure and peat.

Following the potato crop, garden beets were sown in rows 18 inches apart each year. The plants were thinned to stand about 3 inches apart in the row. The results for 1934 to 1941 inclusive are summarized in Table IV.

TABLE IV—AVERAGE TOTAL, ROOT AND TOP YIELDS AND THE ROOT/TOP RATIO PER TREATMENT OF BEETS FROM 1934–41 INCLUSIVE

Treatment	Yields (Bushels Per Acre)			Root/Top Ratio
	Total	Root	Top	
Peat	524	297	227	1.308
Check*	455	261	194	1.345
Manure	524	302	222	1.360
Significant difference 5 per cent point	38.8	23.6	16.1	

*No organic matter added.

The data presented in Table IV indicate that there was no difference in yield between the beets grown on the peat and manure treated plots. However, both of these treatments produced significantly higher yields than did the check plots.

Since the yields varied significantly in the different years the annual yields obtained are of interest. Table V gives the average annual total yields of potatoes in each treatment.

TABLE V—Total Yield of Potatoes in Bushel per Acre for Each Treatment from 1934 to 1941 Inclusive

Treatment	Years								
	1934	1935	1936	1937	1938	1939	1940	1941	Mean*
Peat	74	300	175	172	153	245	216	202	192
Check	82	448	159	176	229	204	202	246	218
Manure	59	376	169	159	167	252	210	171	195

*2 × S. E. difference between mean yields = 7.2 bushels.

It is interesting to note in Table V that the peat plots produced a higher yield of potatoes in five years out of the eight than did the manure but that the difference between the average yields for the whole period in these two treatments is very small. The yield on the check plots was higher than on either the peat or manure plots in five years and lower than either in the other three years. The average yield for the whole period on the check plots was significantly higher than on the other treatments. It should be remembered, however, that the check plot received an application of a complete commercial fertilizer each year from 1935 on while the peat plots received only phosphorus and potash, and the manure no commercial fertilizer with the exception of the year, 1940, when all plots received a complete fertilizer. The average annual root yields of beets in each treatment are presented in Table VI.

TABLE VI—Root Yield of Beets in Bushel per Acre for Each Treatment from 1934 to 1941 Inclusive

Treatment	Years								
	1934	1935	1936	1937	1938	1939	1940	1941	Mean*
Peat	317	103	412	261	324	142	512	301	297
Check	254	133	350	217	299	108	491	236	261
Manure	454	135	371	257	304	137	469	287	302

*2 × S. E. difference between mean yields = 23.6 bushels.

A higher yield of beet roots was obtained on the peat plots than on the manure plots, six years out of the eight, but the difference between the average total yields for the two treatments for the whole period was very small. In contrast to the results obtained with the potatoes, however, the yields obtained on the check plots were lower than those obtained on the peat plots in all years except 1935 and lower than those obtained on the manure plots except in 1940.

Comparing the data in Tables V and VI, it is interesting to note that with the beets the yields on the check plots are in general low while, with the potatoes, they are high. This reversal may be due, to some extent, to the fact that up to 1939 the commercial fertilizer was applied to the check plots at the beginning of the season. A large part of the nitrogen may have been used by the potato plants or leached from the soil before the beets were planted so that there was very little left for the beets. However, in 1939, 1940, and 1941, one-half the nitrogen was applied at the time the beets were planted and still the yield on the check plots was lower than on the peat plots and lower than on the manure plots except in 1940. These results may indicate that the beets are more influenced by a lack of organic matter in the soil than are the potatoes. Observations indicated that germination of beets was slower and the percentage germination lower on the check plots than on the peat and manure plots. Slower germination in particular, might with the short period available for their growth, tend to decrease yields.

CONCLUSIONS

Under the conditions of this experiment conducted for 11 years the peat appears to have kept up the organic matter content of the soil as well or nearly as well as the manure. It appears that under similar conditions finely pulverized peat plus a commercial fertilizer could be used to replace manure in maintaining humus for vegetable production in regions where manure is scarce or expensive, and where peat is relatively inexpensive. Peat has some value as a source of nitrogen. The increased yield of the check plots of potatoes over the peat plots suggests that this nitrogen does not become available in adequate amounts. Hence, in vegetable production, readily available nitrogen as well as potash and phosphorus should be supplied from some other source. In this experiment, potato yields were maintained by the use of commercial fertilizers on plots which had no organic matter for 11 years. Beet yields on the other hand were higher in general on the plots to which organic matter was added.

Some Factors Influencing Fluctuations in Acidity During Periods of Extreme Change in the Moisture Content of Soils

By R. L. CAROLUS and R. E. LUCAS, *Truck Experiment Station, Norfolk, Va.*

DURING 1941 and continuing through the spring and early summer of 1942 rainfall in Eastern Virginia was considerably below normal and very inadequately distributed for satisfactory crop production. Observations indicated that many soils became excessively high in acidity, nitrates, and other soluble salts during this drought. In connection with other investigations several hundred samples of soil were taken from representative truck farms in the section during the drought. A period of excessively rainy weather which followed in August markedly altered the acidity, nitrates and other soluble salts of these soils and made it desirable to resample many of them to determine some of the factors associated with the changes observed. Some of the preliminary results of this investigation are presented in this paper.

EXPERIMENTAL RESULTS

All soils reported in the data given below were taken to a depth of 6 to 7 inches with a plunger type auger, air-dried and their hydrogen-ion concentrations determined with a glass electrode in a (1 + 1) soil water dilution. During the 3-month period previous to the first sampling (dry soil) the recorded rainfall in different locations in the area ranged from less than 6 inches to about 8 inches, approximately 50 per cent of the normal. During the month preceding the August sampling (wet soil) the recorded rainfall varied from 12 to 16 inches, approximately 300 per cent of the normal. The wet soil samples were collected in the immediate vicinity of the first sampling. Portions of the soils collected during the drought were leached, using 60 grams of soil and 60 milliliters of water, allowing the mixture to stand 1 hour, filtering and washing with two 30 milliliters portions of water. The soils were then removed from the filter papers and their pH values determined immediately.

In Table I the data show the changes in pH observed in three

TABLE I—THE INFLUENCE OF FERTILITY LEVEL ON FLUCTUATIONS IN SOIL ACIDITY OBSERVED DURING PERIODS OF EXTREME CHANGE IN SOIL MOISTURE CONTENT

Fertility Level	Number of Samples	pH Dry Soil (a)	pH Wet Soil (b)	Diff. W.S.-D.S.	pH Dry Soil Leached (c)	Diff. D.S.L.-D.S.
High	30	4.71	5.47	0.76 ±0.13*	5.38	0.67 ±0.16*
Medium	26	5.32	5.83	0.51 ±0.18*	5.85	0.63 ±0.15*
Low	24	5.19	5.54	0.35 ±0 14*	5.55	0.36 ±0.08*

(a) Soils sampled after period of prolonged drought June 20 to July 10, 1942.
(b) Soils sampled after period of heavy rainfall (12 to 16 inches) August 20 to 30, 1942.
(c) Dry soils leached in the laboratory (60 grams of soil with 120 milliliter H_2O.).
*Highly significant difference.

groups of soil differing in fertility and sampled as described above. The high level group were obtained from 30 plots of a potato cover crop experiment on which 2000 pounds to the acre of a 6–8–6 or a 6–6–5 fertilizer had been applied annually for a 10 year period. By quick test methods these soils were high in phosphorus. The medium level group were selected from fields that tested medium in both phosphorus and potassium and the low level group from areas that gave a low test for phosphorus. The pH values shown are averages obtained by converting the individual pH values to hydrogen-ion concentrations, averaging and converting back to pH values. The significance of differences between average pH values were determined by "Students" method, and the error is expressed as the probable error. The heavy summer rainfall increased the pH 0.76 units in the fertile soil, 0.51 units in the medium fertile soil, and 0.35 units in the poor soil. In general, laboratory leaching influenced pH about the same extent and in the same manner as rainfall.

Soils are grouped according to their soluble salt concentrations, nitrate nitrogen concentrations and their pH values, at the time of sampling the dry soil, in the data shown in Table II. Soils of low salt and nitrate nitrogen concentration and low pH values when very dry, generally change less in acidity when they become extremely wet than those higher in salt, nitrate and pH value. The correlations between the increase in pH due to rainfall and the soluble salt content of the soils of r = .584± .06; and the correlation between the increase in pH due to leaching a dry soil and its soluble salt content of r = .557± .06 are highly significant. The correlations between nitrate nitrogen content and change in pH due to rainfall or leaching are not significant.

TABLE II—FLUCTUATIONS IN SOIL ACIDITY OBSERVED DURING PERIODS OF EXTREME CHANGE IN SOIL MOISTURE CONTENT

Range of Factor	Number of Samples	pH Dry Soil	pH Wet Soil	Diff. W.S.–D.S.	pH Dry Soil Leached	Diff. D.S.L.–D.S.
A. As Influenced by Soluble Salt Content of the Dry Soils (P P M)						
0–149	6	4.83	5.10	0.27 ±0.19*	5.09	0.26 ±0.05†
150–299	19	5.39	5.72	0.33 ±0 14†	5.92	0.53 ±0.06†
300–449	14	5.71	6.16	0.45 ±0.11†	6.10	0.39 ±0.11†
450–599	10	5.50	6.11	0.61 ±0.26†	6.11	0.61 ±0.17†
Over 600	9	4.90	5.61	0.71 ±0.15†	5.61	0.71 ±0.07†
B. As Influenced by Nitrate Nitrogen Content of the Dry Soils (P P M)						
0–24	18	5.20	5.48	0.28 ±0.10†	5.49	0.29 ±0.07†
25–49	16	5.33	5.73	0.40 ±0.09†	5.91	0.58 ±0.11†
50–74	9	5.55	6.28	0.73 ±0.19†	6.12	0.57 ±0.12†
Over 75	12	5.50	5.99	0.49 ±0.15†	5.97	0.47 ±0.13†
C. As Influenced by the pH Level of the Dry Soils						
4.0–4.49	9	4.33	4.52	0.19 ±0.11†	—	—
4.5–4.99	26	4.68	4.88	0.20 ±0.19†	—	—
5.0–5.49	15	5.16	5.50	0.34 ±0.23†	—	—
5.5–5.99	27	5.72	5.98	0.26 ±0.15†	—	—
6.0–6.49	11	6.22	6.62	0.40 ±0.12†	—	—

*Significance difference.
†Highly significant difference.

Rainfall and leaching materially increased the reaction of dry soils. The figures in Table III indicate that suspending a very dry soil in water (1 + 1) for a period of time will markedly increase the pH of the soil. Coles and Morison (2) also observed that the pH of dry soils increased when the soils were suspended in water for some time. Soils that had been leached either naturally or artificially did not change appreciably when allowed to stand in water.

TABLE III—THE EFFECT OF TIME OF CONTACT WITH WATER BEFORE READING ON THE pH VALUE OF SOILS SAMPLED UNDER VARIOUS CONDITIONS

Soil Moisture Condition	Salt Concentration (P p m)	Time in Contact With Water		
		1 Hour	16 Hours	40 Hours
Sampled during drought	960	4.45*	4.95	5.08
Same—leached	——	5.49	5.48	5.48
Sampled after heavy rains	210	5.47	5.55	5.56

*All pH values are averages of seven samples.

Accumulations of soluble salts, and possibly nitrates resulting from the decomposition of organic matter, tend to favor the replacement of hydrogen-ions from the soil colloid. Drying also tends to increase the ratio of hydrogen-ions to other cations in solution because of a shift in equilibrium in the soil caused by a partial dehydration of the soil colloids resulting in the fixation of such cations as K^+, Ca^{++} and Mg^{++} which have larger ionic radii than hydrogen (6). Rainfall or leaching increases the pH by removing from the soil the acids resulting from the hydrogen-ion replacement, and also by rehydrating the soil colloids. This rehydration releases partially fixed basic cations that move back into the soil solution from the exchange complex through a shift in equilibrium. However, if the soil is not leached but allowed to stand in contact with water for a period of time only the rehydration effect of the colloid is observed.

DISCUSSION

That soil pH is not a fixed value but fluctuates over a considerable range is a common observation. Hester and Shelton (4) found a 0.5 pH unit reduction from December to July in Virginia soils and Hartman (3) found as much as a 0.35 pH unit reduction from April to May in soils on Long Island. On the heavier soils of the middle west Baver (1) found a reduction of as much as 0.9 units from May to September and Kelly (5) observed an increase in pH of 1.0 unit after a heavy rainfall followed a severe drought.

These changes when they occur are more significant from a crop production standpoint in the Coastal Plain soils than on heavier soils, because aluminum toxicity and manganese deficiency become more of a problem when they both occur within a range of less than 1.5 pH units. Spinach growers have observed frequently that soils that become too acid for the crop during a dry fall may be perfectly satisfactory for the same crop during a wet spring; and also that land that had been limed sufficiently to produce spinach satisfactorily during a dry fall sometimes produces light green manganese deficient plants the following spring.

Many of the more fertile potato soils in this section are high enough in pH in the early spring to favor the development of scab, but possibly due to the development of a high salt content favored by rapid evaporation, fall rapidly enough in pH during the late spring to prevent scab development. Liming with reference to the soil pH at potato digging time, frequently has resulted in a reaction favorable for scab development the following spring.

The fact that leaching rains are not required to cause an increase in the pH of soils may explain some of the benefit to the appearance of crops resulting from light showers and irrigation practices. Merely keeping the soil colloids hydrated should not only help maintain a more constant soil reaction but also increase the quantity of replaceable bases available to the plant.

A clearer understanding of some of the factors associated with fluctuations in soil acidity, and a careful consideration of the condition of the soil in regard to moisture content when tested, in relation to the season of the year in which the crop in question is to be grown, should aid in avoiding some of the troubles mentioned above. It would appear desirable to suspend dry midsummer sampled soils in water for 36 to 48 hours before determining their pH for use in making recommendations for crops to be grown under the somewhat more favorable moisture conditions prevailing during the fall. If the crops are not to be planted until spring, after winter leaching has been influential in removing much of the soluble salt, it would appear desirable to use readings on leached samples in making lime recommendations. Lime recommendations made, from early spring determinations of pH values, for summer crops should be somewhat higher than recommendations made from samples tested somewhat later in the season.

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An Experiment on the Physiological Nature of Spindling Sprout[1]

By H. David Michener, *California Institute of Technology, Pasadena, Calif.*

THE condition known as spindling sprout in potatoes is characterized by sprouts which are abnormally small in diameter but which grow at a rate approximating or even exceeding that of normal tubers. In view of the similarity between sprouts from spindling sprout tubers and sprouts from very small seed pieces, it is possible to turn to the latter for suggestions as to the physiological nature of spindling sprout.

Appleman (1) showed that, as the size of the seed piece is decreased below a certain minimum, the sprouts became correspondingly weaker; and he suggested that this was due to the lack of a hormone necessary for normal growth. According to Bushnell (2) the minimum size for normal growth is 1 ounce. For smaller seed pieces, the thickness of the sprouts decreases with the size of the seed piece.

It might be suggested that seed pieces weighing less than 1 ounce lack sufficient carbohydrate to support normal growth of the stem. In this case, however, growth should be normal when growth begins and until the carbohydrate is partly used up. Furthermore, Denny (3) planted 1-ounce seed pieces, allowed the sprouts from them to grow for various lengths of time, and then analyzed the seed pieces. Between the time of planting and the time of emergence from the soil (about 3 weeks) the seed pieces lost less than half of their carbohydrate. The same was true of amino nitrogen, amide nitrogen, and certain other groups of substances. It is therefore extremely improbable that, even in a seed piece much smaller than 1-ounce, lack of any of these substances can exist until some days after the onset of growth. Therefore, the abnormally small stems must result from lack of some unknown substance.

It was suggested further by Appleman (1) that the same substance is lacking in spindling sprout tubers, and that it's lack results in the formation of stems of abnormally small diameter. If this hypothesis is correct, then a stem from a spindling sprout tuber should become normal if grafted onto a sprout from a normal tuber.

In order to carry out such an experiment, Russet Burbank potatoes were selected from a source known to contain both spindling sprout and normal tubers. The spindling sprouts were larger than are sometimes found in this disease. However, they were used because they were readily available and because of the difficulty of grafting extremely small sprouts to normal sprouts.

After sprouting in moist sand, the tubers were planted in flats in such a way that each spindling sprout tuber was in close proximity to one or more normal tubers. They were then grown in a dark room until the stems were about 20 centimeters long, when approach grafts were made between large and small stems. After 5 days, the stem which was to be the stock was cut away above the graft and that which was to be the scion was cut below the graft; thus leaving a spindling sprout scion on a normal stock or *vice versa*. At the same time, diameters of stock and scion were measured. For comparison, grafts were made with a a normal scion on a normal stock. The grafted stems were then grown for 20 days in the dark room, after which measurements were made of the diameter of the main stem of the scion (several centimeters below the tip) and of the largest of any lateral stems which the scion had formed.

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[1] For suggestions regarding this experiment the author is indebted to Dr. F. W. Went and for assistance in carrying it out he is indebted to his wife, Edna P. Michener.

In the grafts which "took" —those in which the scion grew — stock and scion were sufficiently united so that they could not readily be broken apart. Freehand sections showed definite vascular connections in some cases; while in others no vascular connections were found although the scion had grown so much (30 to 60 centimeters) that it seemed certain that a graft union had been formed. Consequently all grafts which had grown more than 10 centimeters during the last 10 days of the experiment were arbitrarily considered to have "taken". Grafts which grew less than this were omitted from the data given below. Unfortunately nearly all the grafts of a normal scion onto a spindling sprout stock fell in the latter classification.

The two right hand columns of Table I give the average change in scion diameter during the 20 days subsequent to grafting. When normal scions were grafted to normal stocks, they remained, on the average, practically the same size and produced laterals which were somewhat smaller. When spindling sprout scions were grafted to

TABLE I—GRAFTING EXPERIMENT WITH SPINDLING SPROUT AND NORMAL POTATO STEMS

Original Diameter (Mm)		Increase or Decrease in Scion Diameter After 20 Days (Mm)		Average Increase or Decrease in Scion Diameter After 20 Days (Mm)	
Stock	Scion	Main Stem	Lateral	Main Stem	Lateral
		A. Normal Stock, Normal Scion			
4.5	5.0	-0.3	-2.6	-0.1	-1.0
3.5	5.5	0.5	-0.9		
4.5	4.5	0.0	-0.5		
5.0	4.5	-0.5	-1.0		
4.5	5.0	0.0	—		
5.5	5.5	-0.2	-1.2		
4.0	4.5	0.0	0.0		
		B. Normal Stock, Spindling Sprout Scion			
7.0	3.0	1.0	1.1	0.9	0.8
4.4	1.5	0.6	—		
5.5	2.0	1.0	0.8		
6.5	2.5	0.5	-0.8		
7.5	3.0	0.2	0.7		
4.5	2.0	0.7	-0.1		
4.0	1.5	3.0	3.0		
5.0	2.0	0.1	—		
		C. Spindling Sprout Stock, Normal Scion			
2.0	5.5	-0.3	-4.0	0.4	-3.8
3.0	6.5	1.0	-4.0		
3.0	6.5	0.5	-3.4		

normal stocks, both main stems and laterals of the scions became larger, although they did not approach the size of the stocks. When normal scions were grafted to spindling sprout stocks, the main stem of the scions became slightly larger but the laterals were very much smaller. It is not known why the main stem was large in this case but it may have grown on stored materials which were used up before the laterals formed. As this last group contained only three grafts, no conclusions can be drawn from it.

As the number of plants is small and the variations between them are relatively large, the measurements of each plant are given in Table I. By comparing grafts in groups A and B, it can be shown that the change in scion diameter subsequent to grafting is significantly different when spindling sprout scions are grafted to normal stocks than when normal scions are grafted to normal stocks. Whether the main stems or the side stems are compared, the odds in favor of significance are greater than 50 to 1.

It has been shown that spindling sprout stems increase in size when grafted onto normal stems. The most reasonable explanation for this is that the spindling sprout stems derive something from the normal stems which they otherwise lack. The spindling sprout tuber may, therefore, lack some substance necessary for normal growth, or it may contain all necessary substances but lack the proper means of moving them to the growing stem.

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Yields of Sweet Potatoes in Southern Indiana as Affected by Date of Harvest[1]

By JOHN D. HARTMAN and F. C. GAYLORD, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

MOST of the vegetable growers on the sandy soils of southwestern Indiana grow only three crops: muskmelon, watermelon and sweet potato. Melon harvests are nearly always completed by late August or early September. Consequently, it is convenient for growers to dig their sweet potatoes in late September or the very first of October, well before the average date of killing frost, October 20 to 22. Most growers have believed in the early digging, even when the crop was to be stored. Demonstrations and observations of W. B. Ward, of the Purdue University Agricultural Extension Service, had indicated, however, that later digging resulted in substantially larger yields. On account of this conflict of ideas with evidence on the subject, it seemed advisable to obtain more data on the amount of the increase which might be expected from delaying the harvesting.

EXPERIMENTAL CONDITIONS AND OPERATIONS

The experiments described in this paper were all on Princeton fine sand near Johnson, Indiana. Each year, from 1937 to 1941, inclusively, long single-row plots were dug about September 30 and corresponding plots on about October 20. The length of plots varied somewhat from year to year as did also the fertilization. These changes were necessary, because of the need of rotating the sweet potatoes to areas of different sizes and shapes and because these experiments were, in some years, run in connection with other experiments. However, each year the plots dug late were protected by guard rows on each side, which were also dug late, and each year the plots of both treatments had equal areas that received any particular soil treatment. Applications of commercial fertilizers in different years supplied from 8 to 80 pounds of nitrogen per acre, from 20 to 200 pounds of phosphoric acid and from 45 to 235 pounds of potash. The 1937 and 1939 experiments were on manured land. Plot lengths varied from 278 feet to 440 feet. Number of replications was four in 1937 and 1938 and five in subsequent years.

All data were submitted to an analysis of variance in the regular manner. In combining the results for several years, plot yields were converted to bushels per acre. Each replicate was then given equal weight. Since there were only four replicates in the first two years and five in the others, data for either of these two years did not have quite as much effect on means for two or more years as did data for 1939, 1940 and 1941.

A Little Stem Yellow Jersey strain, which probably came originally from Frank B. Shaw, of Swedesboro, New Jersey was used the first three years. In the other two, the Muscatine 3 strain of Jersey, originated by the Iowa Agricultural Experiment Station, was grown.

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[1] Journal Paper No. 68, Purdue University Agricultural Experiment Station.

RESULTS AND DISCUSSION

Rainfall, date of planting and harvest, as well as resultant yields of sweet potatoes, are presented in Table I. Only precipitation exceeding 1 inch, in total, for a single day or consecutive days was listed, because it is unlikely that lesser rains did the plants much good. Probably the portion in excess of ½ inch was the really significant part.

TABLE I—EFFECT OF TIME OF HARVEST AND OF RAINFALL ON YIELDS OF SWEET POTATOES

Date of Harvest	Yields of Sweet Potatoes (50-Pound Bushel Per Acre)			Important Precipitations‡ From July 1 to Date of Last Harvest
	Number 1 Grade	Marketable	Total	
			Planted May 13, 1937	
Oct 1	147	198	198	2.03 (Jul 16); 1.79 (Aug 22); 1.53 (Sep 10–11); 2.46 (Oct 2–5); 4.29 (Oct 17–18)
Oct 20	230*	285*	285*	
			Planted May 25, 1938	
Sep 30	100	143	143	3.02 (Jul 12); 1.94 (Jul 17–18)
Oct 22	127*	164	164	
			Planted May 6, 1939	
Sep 30	124	149	154	1.66 (Jul 3); 1.12 (Aug 7)
Oct 17	134	159	165	
			Planted May 20, 1940	
Sep 30	47	58	59	1.12 (Jul 11–12); 1.10 (Sep 24–25)
Oct 21	48	64	72	
			Planted May 12 and May 16, 1941	
Sep 30	46	63	91	1.69 (Jul 1–2); 2.02 (Aug 19); 1.92 (Oct 1–4); 2.32 (Oct 14–15)
Oct 22	149†	186†	230†	
			Average for 1937 and 1941	
Early	91	123	138	
Late	185†	230†	254†	
			Average for 1938, 1939 and 1940	
Early	90	115	117	
Late	101*	129*	132*	
			Average for All Five Years	
Early	90	118	125	
Late	134†	167†	180†	

*Yield for late digging significantly greater than yield at early harvest with odds of 19:1.
†Yield for late digging significantly greater than yield at early harvest with odds of 99:1.
‡Important precipitations were all precipitations which exceeded 1 inch during consecutive days

It is undoubtedly true that the readily available soil moisture resulting from the 1.10-inch of rain which fell on September 24 and 25, 1940 was exhausted within a few days, especially because it followed such a long drought. If so, then the data may be said to show that, when the soil was wet after September 30, an acre in sweet potatoes produced 5 to 6 bushels (total) per day, and when the soil was dry, the same area produced ½ to 1 bushel per day.

Yields at the September 30 or October 1 harvests were obviously determined largely by rainfall during the summer and, to a lesser extent, by the slope of the land. The 1938 and 1939 crops were grown on nearly level ground, where drainage was not so rapid, while the 1940 crop was on an especially steep slope. In no case, however, was there a water table close enough to the surface to benefit the plants.

For the five years, as a whole, delaying digging was a good practice to be recommended wherever practical. Also a need for irrigation was indicated.

In 1939 and 1940, when the soil was dry in October and the average increase in yield due to delay in digging was small, soil rot continued to develop during the time between the two diggings. At the late digging more potatoes had to be thrown out of the marketable grades because of lesions due to the soil rot disease than at the early digging. When the soil was moist in October, 1941, however, there was no increase whatsoever in soil rot. These facts seemed to indicate a tendency of the soil rot lesions to develop during periods of drought rather than in periods when the soil was moist.

Losses due to cracking, on the other hand, were much greater at the late harvest in 1941 than at the early.

SUMMARY

Delaying the digging of sweet potatoes in Indiana from about September 30 to October 20 or 22 increased yields remarkably in years when the soil was moist during the first three weeks of October.

Effect of Temperature on Yield of the Sweet Potato[1]

By El Sayed M. Sakr, *Cornell University, Ithaca, N. Y.*

THE Porto Rico variety of sweet potato was used in this work to determine the effect of temperature during growth of the plants on yield prior to setting in the field. Cuttings were made from a plant kept at 60 to 70 degrees F and potted in 4-inch pots on February 11, 1942. The pots were placed in a greenhouse kept at 70 to 80 degrees F under the normal length of day prevailing in Ithaca, New York until March 2 when the plants were divided into two groups, one was left at 70 to 80 degrees F and the other was transferred to 50 to 60 degrees F under the normal length of day in both houses. The average number of leaves per plant was 2.75 at the time of the transfer. These ranges of temperature could not be maintained after the first of May because of the rise in temperature outside. It is thus assumed that the plants in the cool house had an exposure to this temperature of about 2 months. On June 13, the plants in both houses were taken to the field and planted 3 by 3 feet apart. The field had been fertilized with manure at the rate of 10 tons per acre plus 1000 pounds of 5–10–5 commercial fertilizer. The plants that had been in the cool house were noticeably smaller than the ones grown previously in the warm one. All the plants were staked and left in the field until October 5 when the cool weather arrived and some of the upper leaves were killed.

RESULTS AND CONCLUSIONS

At harvest, the weight of roots and vines per hill was taken. Also, 25 roots of each treatment were taken at random and weighed. Only the mean weight is presented in the following table.

Treatment	Number of Plants (Hills)	Weight of Roots Per Hill (Ounces)	Weight of Vines Per Hill (Ounces)	Weight of Individual Roots (Ounces)
Plants exposed to low temperature	32	52.0	52.0	10.20
Plants not exposed to low temperature . .	37	69.0	54.0	23.68
Odds	—	>9999:1	1:1	>1033:1

It is seen from the table that the difference in yield per hill and in weight per root can hardly be due to chance. However, there was no difference in vine weight at harvest because the plants previously exposed to low temperature caught up with the ones which had been in the warm house. It was noticed, also, that the number of roots per hill was greater for the plants previously exposed to low temperature than for those which were grown in the warm house as shown in Fig. 1. From the figure it can be seen, also, that the roots from the plants kept in the warm house were overmature and started to crack.

The difference in yield might be explained by the fact that the plants in the warm house had much greater growth than those kept in the cool greenhouse. At the time when the plants were transferred to the field, for instance, the average number of leaves per plant was 17 and 168 for the plants from the cool and warm houses respectively. It was noticed at that time that, while the plants in the warm house were trailing and each had several branches, the ones in the cool house were not branched and were stunted. In addition, the leaves of the plants in the warm house were dark green, while those of the plants in the cool house were tinged with red, which is an indication of the effect of cold.

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[1] Paper No. 252, Department of Vegetable Crops, Cornell University, Ithaca, New York.

FIG. 1. Left, roots harvested from plants grown at 70 to 80 degrees F prior to planting in field. Right, roots from plants exposed to 50 to 60 degrees F prior to planting in field.

This study suggests the possibility of raising sweet potatoes in regions of relatively short, cool-growing seasons, provided the plants are started in a warm greenhouse considerably in advance of the time they are set in the field.

The Influence of Different Methods of Handling on the Keeping Quality of Stored Jersey Sweet Potatoes[1]

By John D. Hartman and F. C. Gaylord, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

IN SPITE of recommendations of extension and experiment station men, southern Indiana growers continue to handle their sweet potatoes roughly at harvest time. It is general practice to pull the roots from three rows at a time and to throw the potatoes from these three rows into a single long pile along the line of the central row. Furthermore, laborers ordinarily do not lay the potatoes in the standard tub-shaped bushel baskets, but, instead, drop or even throw them into the containers. Baskets are filled so full that it is difficult to fasten the projecting veneer strips of the lids in the wire handles. This situation seemed to call for determinations, under Indiana conditions, of the benefits of careful handling. Five methods of handling were compared over a period of 4 years. Loss of weight during storage and the condition of the potatoes at the end of the storage period were taken as the criteria for comparisons.

METHODS

Little Stem Jerseys, grown on fine sand at the Southwestern Indiana Horticultural Experimental Farm, served as the test material. The strain harvested in 1938 came originally from Frank B. Shaw, of Swedesboro, New Jersey; in the other three years Muscatine 3, developed by the Iowa Agricultural Experiment Station, was used.

The treatments in 1938 were as follows:

1. *Commercial:*—Sweet potatoes were thrown together, three rows onto one, at digging, and thrown or dropped into the baskets. Baskets were filled so that the lids bulged about 3 inches above the rims and then were stacked roughly on top of each other for hauling.
2. *Full, Without Liner:*—Sweet potatoes were laid or dropped on soft sand at digging and laid in baskets. Baskets were filled to a 3-inch bulge, but handled with reasonable care.
3. *Not Full:*—Same as treatment 2, except that baskets were filled not quite to their rims.
4. *Crate:*—Same as treatment 3, except that rigid wooden crates were used in place of the baskets. The slats of these crates were spaced about ¾ inch apart and were unplaned on the inside though they were sawed rather smooth.

In 1939 a fifth treatment was added:

5. *Full, With Liner:*—Same as treatment 2, except that simple cardboard liners were placed in the baskets and corrugated cardboard pads under the lids.

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[1] Journal Paper No. 81, Purdue University, Agricultural Experiment Station.

As may be readily seen, the experiment was designed to permit a series of comparisons between treatments differing in one respect only. Treatment 2 was the same as treatment 1 except in care in handling. In a similar way treatment 2 could be paired with 3, 3 with 4, and 2 with 5.

All stored potatoes were of U. S. No. 1 grade, except possibly with the respect of skinning. Baskets were true tub bushels, with reinforcing rims around the bottoms. After filling, the lid of each basket was wired fast and each crate was closed with slats nailed across the top.

The filled or partially filled containers were hauled about a half mile over rough roads to a modern commercial sweet potato storage. The wagon used in 1938 had steel rims. It was drawn at a speed of four or five miles per hour. In consequence, the crates and baskets were shaken up considerably. Potatoes in the partially filled baskets and in the crates frequently hit the lids. In subsequent years, rubber tires were substituted for the steel rims and jolting was much less.

Five bushels of each treatment were stored each year. One bushel of each treatment was considered to belong to a single block. Bushels of such a single block were harvested from a single small area in the field and were stored together at a single level. Treatments were randomized within blocks. All this experimental material was placed at the back of a bin where it was not disturbed until the end of the storage period.

Storage temperatures were maintained at about 80 degrees F during the curing period, which varied from 1 week to 10 days, and thereafter at the rather high level of 60 degrees F.

Storage periods began October 12, 1938, October 14, 1939, October 17, 1940, and October 16, 1941. They ended on April 5, 1939, April 6 to 8, 1940, April 4, 1941 and April 7, 1942.

In the spring the sweet potatoes in each basket were carefully sorted into three groups: (a) marketable potatoes with only few and very small scars resulting from skinning in the fall; (b) marketable potatoes with more than ½ square inch of surface scars; and (c) potatoes unmarketable because of decay. The weight of unmarketable potatoes was a measure of the loss due to decay, but not an exact measure, because in many cases the decayed potatoes had become mummified and hence retained only a fraction of their original weight. Weights of potatoes in each class were expressed as percentages of the total weight of potatoes stored in the basket in the fall.

RESULTS AND DISCUSSION

As is shown in Table I, keeping quality as a whole was poorest in 1938–1939. This effect was probably chiefly due to the use of the Shaw Jersey strain, which is evidently much more susceptible than is Muscatine 3 to surface rot and fusarium end rot.

For the 4-year period careful handling was significantly superior to commercial handling in weight of total marketable and unskinned marketable potatoes. The normal shipping point price of No. 1 Indiana

TABLE I—KEEPING QUALITY OF SWEET POTATOES WITH VARIOUS METHODS OF HANDLING AND PACKAGING

Years	Length of Storage Period (Days)	Grade of Sweet Potatoes at End of Storage	Weight of Sweet Potatoes of Each Grade at End of Storage Period (Per Cent of Original Total Net Weight)					
			Treatment Number and Name					Difference Necessary for Significance (19:1)
			1 Commercial	2 Full Without Liner	3 Not Full	4 Crate	5 Full With Liner	
1938-39 ..	175	Total marketable	63.3	73.7	77.5	72.7	—	N.S.
		Marketable unskinned	25.4	54.8	61.2	49.9	—	11.4
		Unmarketable	20.4	14.2	10.4	13.1	—	N.S.
1939-40...	176	Total marketable	75.7	78.5	81.7	80.5	83.5	4.8
		Marketable unskinned	39.8	54.6	51.2	51.7	63.1	13.2
		Unmarketable	7.0	6.0	5.0	4.0	3.0	N.S.
1940-41 .	169	Total marketable	70.1	76.5	75.0	62.1	78.8	10.3
		Marketable unskinned	35.2	61.2	61.2	47.6	61.8	15.2
		Unmarketable	9.5	5.3	6.9	14.5	5.0	6.6
1941-42 .	173	Total marketable	85.0	84.8	86.8	84.9	85.4	N.S.
		Marketable unskinned	56.1	76.8	84.6	79.4	79.3	6.4
		Unmarketable	2.6	2.5	1.2	1.8	1.6	N.S.
All four years	—	Total marketable	73.6	78.4	80.2	75.0	—	4.0
		Marketable unskinned	39.1	61.9	64.6	57.2	—	5.8
		Unmarketable	9.8	7.2	5.8	8.4	—	2.7
Last three years . .	—	Total marketable	77.1	79.9	81.1	75.8	82.6	3.7
		Marketable unskinned	43.7	64.2	65.7	59.5	68.1	6.7
		Unmarketable	6.2	4.7	4.2	6.8	3.2	2.4

Jersey sweet potatoes in April is about $1.50 per 50-pound bushel. This is for potatoes which usually have more scarring than strict adherence to U. S. grades would permit. Without taking into consideration the differences in scarring, the value in the fall of a full bushel (55 pounds) carefully handled would be about 8 cents more than that of one roughly handled. In normal times the extra labor required to handle the sweet potatoes carefully would be very much less than 8 cents. If a premium were paid for freedom from scars, the difference in favor of careful handling would be much greater. For example, if $2.00 were paid in April for strictly U. S. No. 1 potatoes, and if half the skinned marketable potatoes had to be sold as No. 2's at $1.00, then on the basis of the 4-year averages, a bushel of carefully handled potatoes would, in the fall, be worth 20 cents more than a bushel roughly handled.

Thompson and Beattie (1) have reported on similar comparisons of careful and commercial handling. Their averages for 4 years show that with careful handling total losses were 7.97 per cent of the original weight and with commercial handling 13.00 per cent. The difference, 5.03 per cent, is almost exactly the same as the 4-year average difference obtained in these experiments. Thompson and Beattie worked with the varieties Nancy Hall and Dooley and with storage periods somewhat shorter than those considered in this paper. Anderson and Edmond (2) using the Triumph variety, report total losses of 9.98 per cent for commercial handling and 5.41 per cent for careful handling.

The rigid crate with rather rough slats proved unsuitable as a container for stored sweet potatoes, since the data for 4 years show that treatment 3 was clearly superior to treatment 4. This difference might have been due partly to the greater interior roughness of the crate and partly to its excessive ventilation. A comparison of percentages of skinned potatoes suggests that roughness was a factor.

Bushels filled partly full held only about 40 pounds of potatoes as compared with 55 pounds in treatment 2. Storage charges for a bushel basket of No. 1 potatoes amounted to 10 cents whether or not the basket was full. Consequently, the cost of storing 55 pounds of sweet potatoes in treatment 3 was about 14 cents. By calculations corresponding to those for the comparisons of treatments 1 and 2, treatment 3 would be slightly more profitable than treatment 2 if the potatoes were graded strictly in accord with U. S. Standards. Otherwise, treatment 2 would be more economical.

As a method for protecting sweet potatoes in storage, treatment 5 seems better and cheaper than treatment 3. However, the means for the last 3 years do not show a significant superiority of treatment 5 over treatment 2. The total cost per bushel of liners and pads is about 3 cents. Their value in use would average from 4.5 to 6.5 cents a bushel, the variation depending on whether or not a reasonable premium would be paid for quality.

From the means for 4 years substituted in appropriate pairs of simultaneous equations, it was possible to calculate that, on the average, potatoes that did not rot had lost 8.3 per cent of their original weight and ones that were unmarketable had lost 52.2 per cent of their original weight. The latter figure agrees with rough estimates made on the basis of the average appearance of the unmarketable sweet potatoes at the end of the storage period. As was previously mentioned, many of these roots had become hard and mummified.

When corresponding percentage losses for sound and for unsound potatoes were figured from the 4-year means for treatment 1, 2, and 3 only, and the resultant values used in calculating the hypothetical original weight of potatoes stored in crates, it was found that calculated weights agreed very closely with known total original weights. Therefore, practically all loss in weight in crates was accounted for and there was no reason to believe that the excessive ventilation of the crates had been detrimental or beneficial. Some growers believe it important that the sweet potato storage package have much ventilation. The above calculations and the fact that treatment 5, with least ventilation, was the best treatment tend to indicate that their belief is not well founded.

SUMMARY

In a study extending over a period of 4 years, it was found that sweet potatoes carefully handled at digging time kept better than potatoes handled in the usual commercial manner. This comparison was made on material packed in tub bushel baskets. Baskets were filled so full that lids bulged 3 inches above the rims. No liners or pads were used. At the end of storage periods ranging from 169 to 175 days, an average of 78.4 per cent of the original weight of care-

fully handled sweet potatoes remained as a marketable product while the corresponding value for commercial handling was 73.6 per cent. The weight of unscarred marketable potatoes at the end of the storage period was 61.9 per cent of the original total weight for careful handling, but only 39.1 per cent for commercial handling.

Carefully handled sweet potatoes stored in baskets with liners and pads kept very well, whereas storage in rigid wooden crates was less satisfactory.

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Post-Harvest Conditions Affecting the Sugar Content of Potato Tubers in Cold Storage

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ABSTRACT

The complete data will be given in a paper that is to appear in Contributions from Boyce Thompson Institute.

AT various periods of time after harvest tubers of six varieties were placed in four different storage conditions in respect to temperature and humidity and after various lengths of time under these prestorage conditions, they were then placed at 5 degrees C. Although the sugar contents of the tubers were not different at the end of the prestorage periods these lots subsequently showed differences in the rate of development of both reducing sugar and sucrose during cold storage at 5 degrees C.

Spartan Hybrid—A First Generation Hybrid Tomato for Greenhouse Production[1]

By Keith C. Barrons, *Michigan Agricultural Experiment Station, East Lansing, Mich.*

INCREASING competition from southern and western grown vegetables, frequently resulting in lower prices, has brought the greenhouse vegetable grower to the realization that he must attain maximum production if he is to continue in business. Considerable research in the field of insect and disease prevention and fertility control has enabled producers of greenhouse crops to obtain higher average yields and thus decrease production costs. If advantage is taken of our present knowledge of production methods there appears to be little a grower can do to increase yields with those varieties now in use. More vigorous varieties with a higher yield potential would make increases possible at little if any increase in cost. The improvement of corn yields made possible by the use of commercial hybrids suggested the possibility of utilizing hybrid vigor in the tomato which is the most important greenhouse vegetable crop.

Breeders have frequently observed the occurrence of hybrid vigor in the tomato and a few workers have measured the increases in yields exhibited by certain hybrids. The literature pertaining to the subject has been reviewed by Barrons and Lucas (1). These workers suggested methods whereby first generation hybrid tomato seed may be produced on an extensive scale. The conclusion was drawn that such seed might be too costly for a field crop but for greenhouse production its use is entirely feasible.

PRESENTATION AND INTERPRETATION OF EXPERIMENTAL DATA

Simultaneously with these seed production experiments the writer made observations on the yielding ability of numerous first generation tomato hybrids under field conditions. Several hybrids involving Michigan State Forcing as one parent appeared very promising. This variety has proven to be the most satisfactory for greenhouse production in Michigan. When it was decided to test some hybrids for adaptability to greenhouse conditions it appeared logical to include several produced by hybridizing Michigan State Forcing with other high yielding varieties.

Hybrids of Michigan State Forcing and six leading field varieties, namely, Marglobe, Rutgers, Stokesdale, Valiant, Pritchard, and Cooper's Special, were placed in preliminary tests. In addition, four hybrids of Michigan State Forcing and other forcing varieties, namely, Globelle, Vetomold, Bay State, and Grand Rapids Forcing, were included. Based on these tests the hybrids involving Cooper's Special, Vetomold, Bay State, and Globelle were chosen as the most outstanding. With Michigan State Forcing for comparison they were subjected to

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[1] Journal Article No. 624 (n.s.) from the Michigan Agricultural Experiment Station.

replicated plot yield tests in the spring and fall of 1941 and the spring of 1942.

Plots consisted of five plants and three replications were made. For the spring tests seed was sown during the first half of January and plants were flatted when large enough to transplant. They were set in ground beds during the third week in February and spaced 18 inches by 36 inches. Recommended growing methods were employed and it appears doubtful that any controllable factors limited yields to an appreciable degree.

The mean yields of marketable fruit from the two spring crops are presented numerically and graphically in Fig. 1. The yield data was subjected to a variance analysis and the differences found necessary for significance are 2.4 pounds and 1.7 pounds at the 5 per cent and 1 per cent level, respectively. It will be noted from Fig. 1 that Michigan State Forcing x Globelle and Michigan State Forcing x Cooper's Special produced a significantly higher yield than Michigan State Forcing itself at the 1 per cent level. Michigan State Forcing x Vetomold and Michigan State Forcing x Baystate are superior to Michigan State Forcing at the 5 per cent level. Michigan State Forcing x Cooper's Special is significantly better than Michigan State Forcing x Vetomold at the 1 per cent level and to Michigan State Forcing x Baystate at the 5 per cent level.

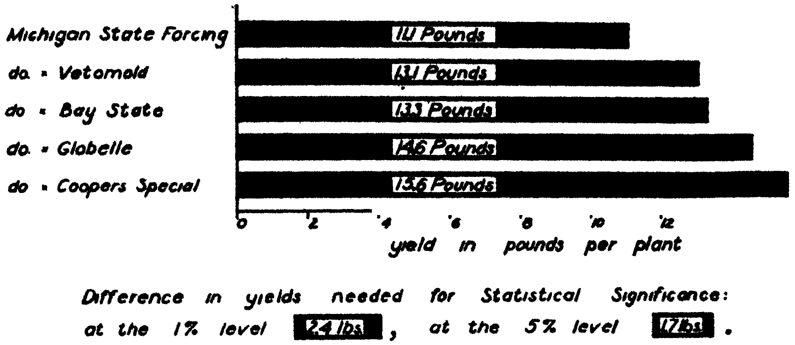

FIG. 1. Graphic presentation of mean yields per plant of Michigan State Forcing and four first generation hybrids of Michigan State Forcing and other varieties. Data is for two spring crops. Plots consisted of five plants with three replications in each year.

Few greenhouse growers in Michigan produce fall tomatoes because of the consistently low yields and high fuel costs. The low incidence of sunshine prevailing during late October, November, and December coupled with short days undoubtedly accounts for the lack of productivity. A fall test planting was made in 1941 in order to determine whether any of the hybrids would produce a sufficiently greater yield to warrant more extensive planting for fall harvest. Seed was sown on June 30, seedlings were flatted July 12 and shifted to 4-inch pots on August 3. Plants were shifted to ground beds on August 16, and harvest extended from October 18 to January 10.

Yields of the 1941 fall tests in pounds per plant are as follows:

Michigan State Forcing x Globelle	4.6 pounds
Michigan State Forcing	4.7 pounds
Michigan State Forcing x Bay State	5.6 pounds
Michigan State Forcing x Cooper's Special	5.6 pounds
Michigan State Forcing x Vetomold	5.7 pounds

A variance analysis of the yield data revealed that Michigan State Forcing and Michigan State Forcing x Globelle gave a significantly lower yield that the remaining hybrids. It is interesting to note that Michigan State Forcing x Globelle which was the second highest yielding hybrid in the spring tests produced even less than Michigan State Forcing in the fall test. Furthermore, Michigan State Forcing x Baystate and Michigan State Forcing x Vetomold were among the top yielding hybrids in the fall experiment but were significantly lower in yield than Michigan State Forcing x Cooper's Special in the spring tests. No doubt varietal differences exist in the efficiency of light utilization under varying day lengths and light intensities.

The increase in yield of about a pound per plant which certain hybrids would apparently make possible is hardly sufficient to encourage more extensive production of greenhouse tomatoes as a fall crop. Where fall tomatoes are being produced at the present time the results of this limited test would certainly indicate the advisability of a thorough-going commercial trial.

A number of commercial greenhouse tomato growers tested the four hybrids under investigation in the spring of 1942. With one exception they expressed the opinion that the hybrids in general were probably superior in yielding ability to Michigan State Forcing. Three of the growers were outstandingly in favor of Michigan State Forcing x Cooper's Special, while two others chose both this hybrid and Michigan State Forcing x Bay State as being worth further trial.

Description of Spartan Hybrid

Because it produced significantly more than all but one hybrid in the spring tests and outyielded this one in the fall, Michigan State Forcing x Cooper's Special may be considered the highest yielding tomato in the tests. This high potential yield together with a number of other desirable traits prompts its introduction as a greenhouse tomato under the name Spartan Hybrid.

Cooper's Special itself is a determinate variety, and although determinate is recessive to indeterminate habit of growth Spartan Hybrid apparently inherits short internodes from its Cooper's Special parent. Thus flower clusters are enough closer together that one more is produced up to the height at which the plants are topped than on Michigan State Forcing or other indeterminate varieties. The extra flower cluster coupled with an apparent more rapid rate of growth is probably responsible to a large degree for its high yield. An inspection of the harvest data revealed that all four hybrids are a week to 10 days earlier than their Michigan State Forcing parent. Thus much of the extra yield comes early in the season which, for the spring crop, is the period when the highest prices are realized.

Spartan Hybrid produces medium to large fruit averaging 4.5 to 5.0 ounces in weight. The shape is a slightly flattened globe with an average shape index of 86 per cent. The percentage of unmarketable fruit is no greater than that of Michigan State Forcing which is noted for its smoothness. Limited observations indicated that Spartan Hybrid is less subject to cracking than its Michigan State Forcing parent. Although Cooper's Special is a "pink" fruited, (colorless skinned) variety Spartan Hybrid is fully as red as Michigan State Forcing due to the complete dominance of red fruit color over pink (yellow skin over colorless).

Among the other hybrids Michigan State Forcing x Globelle has the objectionable feature of longer than average internodes making an excessively tall plant. Some fruit of this hybrid tend to be rough especially on the first cluster. Michigan State Forcing x Vetomold and Michigan State Forcing x Bay State are intermediate in size and both would be worth trying where the market discriminates against larger fruits.

DISCUSSION

There appears to be little doubt that the extra cost involved in producing seed of first-generation hybrid tomatoes can be highly profitable for the greenhouse operator. One Michigan grower has already gone into the production of hand pollinated first-generation hybrid seed for his own use and will plant a considerable proportion of his range to Spartan hybrid in 1943. It is hoped that some commercial seedsmen will see fit to produce this and other hybrids in the near future. It will be obvious to those familiar with the history of hybrid corn that we have merely "scratched the surface" with respect to discovering the best possible tomato hybrid for greenhouse use. It is not unlikely that more productive hybrids would be found if an extensive testing program were conducted involving many varietal combinations.

The question might well be asked as to the likelihood of sufficient genetic impurities existing within Michigan State Forcing and Cooper's Special to warrant further controlled inbreeding followed by tests of various line combinations. Such a procedure might yield profitable results and should be undertaken if Spartan Hybrid achieves sufficient importance to warrant the expense involved. It should be borne in mind, however, that because of natural self-pollination commercial tomato varieties tend toward homozygosity to a rather high degree. Myers and Peacock (2) reported differences in yield of reciprocal crosses in tomatoes. Yield tests were not conducted for any of the reciprocal crosses for any of the varietal combinations included in these experiments. However, observational tests of a few reciprocal crosses including Cooper's Special x Michigan State Forcing did not reveal any differences. Because of its determinate habit of growth Cooper's Special is ill adapted to the usual system of pruning and training which is essential to the efficient large scale production of hybrid seed. Possibly Cooper's Special could be used as the female parent if a suitable method of training was devised. The yield of seed per pollination would probably be greater than when Michigan State Forcing is employed as the female parent. It would be unwise, however, to use Cooper's Special as the female without first subjecting this reciprocal cross to a careful yield test.

As previously mentioned Barrons and Lucas (1) have described methods whereby hand pollinated seed may be produced in quantity with a minimum amount of labor. They found greenhouse conditions during March and April to be especially favorable for the set of fruit from hand pollination containing a good quantity of seed. This is an especially busy period for most greenhouse operators, and it is costly to use valuable greenhouse space for seed production when this seed might just as well be produced under field conditions during the summer. For best results from field pollinations a cheesecloth shade over the female plants is suggested. Some growers have more time to spare during the fall and hand pollinated seed may be produced efficiently at that time of the year. Sowings should be made to bring the plants in bloom at about the time cool weather begins during the late summer. The writer obtained fair results with late summer and fall pollinations in 1942, but the number of seed per fruit was very low from pollinations made after October 15. Seed from pollinations made up until that date will ripen in time to plant the spring crop by January 1.

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Field Response of Tomatoes to Large Applications of Phosphates[1]

By J. M. Ingram, E. C. Stair, and J. D. Hartman,
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TOMATOES in experiments on light colored and medium brown silt loams of northern Indiana have, in general, shown no marked responses to superphosphate applied in bands at rates of 750 to 900 pounds per acre. Yet on these same soils tissue tests made during the harvest season have generally indicated that the plants were deficient in phosphorus (3, 4). Extractions of such soils with 0.1 per cent acetic acid have also usually shown little readily available phosphate.

In the experiments reported in this paper very large amounts of superphosphate were applied for the purpose of determining whether the soils in question are really markedly deficient in phosphorus and of initiating studies on the feasibility of satisfying their phosphate-fixing capacities. It is generally considered impractical to satisfy the fixing capacity of field soils, but tests made by Bushnell (1) and by the junior author on market garden and greenhouse soils prove that under commercial conditions some loams are built up to the point where they are abundantly supplied with phosphates soluble in water or in 0.1 per cent acetic acid.

Experiment on Kern Silt Loam

The experiment consisted of nine treatments, which are outlined in Table I. Four-plant plots, 8 by 8 feet, were arranged in four randomized complete blocks. A guard row was set around the border of the experimental area, but there were no guards between plots.

TABLE I—Outline of Treatments

Materials Applied (Pounds Per Acre)	Treatment Numbers									
	1	2	3	4	5	6	7	8	3	9
	Low nitrogen and Potash Series			High Nitrogen and Potash Series				pH Series		
20 per cent Ammonium sulfate	100	100	100	800	800	800	800	100	100	100
20 per cent Superphosphate	0	200	1200	200	1200	9600	28800	1200	1200	1200
50 per cent Muriate of Potash	120	120	120	400	400	400	400	120	120	120
Hydrated Lime	3000	3000	3000	3000	3000	3000	3000	0	3000	5000

Kern silt loam is a medium brown soil which contains about 4 per cent organic matter. The land where the experiment was located had a pH of about 5.0 before liming. According to the Purdue rapid tests (5), it was low in available nitrogen and phosphorus and medium in potash.

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[1] Journal Paper No. 61, Purdue University Agricultural Experiment Station.

On May 23 the fertilizer was broadcast on the soil within a radius of 1¾ to 2 feet of the points where plants were to be set. It was spaded into and well mixed with the soil it had covered. The hydrated lime was applied on May 25 and also well mixed with the soil.

Indiana Baltimore tomato plants, grown in flats in hotbeds, were transplanted directly to the field on May 29. Some of these plants were injured by grasshoppers and cutworms and were replaced on June 8 with plants of equal size but of somewhat greater succulence.

The plant heights were measured on June 15. On July 4 both height and diameter were recorded. From the two measurements of July 4, the approximate average volume occupied by the plants was calculated.

The harvesting season lasted from July 29 to September 23. The total number and weight of fruits picked on each date was recorded as total yield; the number and weight of fruits in satisfactory condition for sale to a cannery operating under the U.S. grades were tabulated as marketable yield. The early total yield was the total yield for the first third of the season.

Rapid plant tissue tests were made by R. K. Showalter on all plots on August 19. The methods used were modifications of the procedures described by Thornton, Conner, and Fraser (5). In summarizing the phosphate readings the value of 1 was substituted for each very low test, 2 for each low test, 3 for each medium test, 4 for each high test, 5 for each very high test, and 6 for each very very high test.

Glass electrode tests for pH were made of soil samples taken from the field on September 24. These samples were all taken from the portion of the soil with which the applied fertilizer had been mixed.

The amount of foliage left on the plants at the end of the season (September 23) was estimated numerically by giving plants with almost no foliage a rating of 1 and those with perhaps one-half to three-fourths their maximum leaf area a rating of 9. Plants with intermediate amounts of foliage were rated accordingly.

The amount of available P_2O_5 in the soil was determined by a procedure described by Hartman (2). Twenty grams of soil were shaken for 2 minutes with 50 milliliters of a solution containing 1 milliliter of glacial acetic acid per liter. The whole mixture was then poured on a filter. The amount of P_2O_5 thus extracted was calculated in terms of pounds per acre of soil. However, the figures so obtained do not represent the total amounts extractible with a 0.1 per cent acetic acid solution. In fact, each successive extraction with the same kind of solution on the identical soil sample removed almost as much phosphorus as did the preceding extraction. Hence the values obtained with a single rapid extraction represent only a fraction of the soluble phosphorus.

In working out the analysis of variance of results of soil tests, it was necessary to transform the readings to their logarithmic forms, because with the readings themselves there was an obviously high correlation between the size of the means and that of the standard errors.

The principal data obtained in the experiment are presented in Table II.

TABLE II—SOIL CONDITIONS, PLANT GROWTH AND YIELDS RESULTING FROM VARIOUS PHOSPHORUS TREATMENTS ON KERN SILT LOAM

	Low Nitrogen and Potash Series			High Nitrogen and Potash Series				pH Series			Difference necessary for Significance
	P₂O₅ Applications (Pounds per Acre)										
	0	40	240	40	240	1920	5760	240	240	240	
pH of soil	5.83	5.95	5.91	5.36	5.53	5.51	5.11	4.98	5.91	6.07	0.44
Plant height on June 15 (Inches)	8.5	9.1	11.1	8.0	9.6	9.7	9.0	10.1	11.1	10.8	—
Approximate volume of plant on July 4 (cubic feet)	.97	1.74	3.35	1.08	1.87	2.56	1.87	2.71	3.35	2.89	—
Early total yield (tons per acre)	1.6	2.3	4.2	1.4	2.8	3.9	3.1	3.4	4.2	3.3	1.3
Marketable yield for whole season (tons per acre)	9.8	12.1	16.6	9.4	16.4	20.0	21.8	15.0	16.6	19.0	6.3
Total yield for whole season (tons per acre)	12.4	17.3	22.8	12.2	22.2	27.7	26.6	19.6	22.8	24.3	7.3
Estimated abundance of foliage on September 15 (arbitrary units explained in text)	3.0	4.0	4.5	4.0	5.5	7.0	8.0	4.5	4.5	6.0	2.1
Results of tissue test made on August 17 (arbitrary units explained in text)	2.3	3.0	2.3	2.3	3.3	6.0	6.0	3.5	2.3	2.8	1.3
Available P_2O_5 in soil (pounds per acre)	.46	.42	1.48	.46	2.57	53.70	537.00	8.32	1.48	1.66	—
Logarithm of ten times available soil P_2O_5	0.66	0.62	1.17	0.66	1.41	2.73	3.73	1.92	1.17	1.22	0.83

Most of the foliage late in the season consisted of new leaves. There was no clear indication that phosphates protected the plants against defoliating diseases, but it was easy to see that much more new growth was obtained on high phosphate plots.

From the results of the high nitrogen and potash series, it appears that the relation of growth and yields to phosphate application followed, as shown in Fig. 1, a typical logarithmic curve, with nearly maximum yield obtained at about 2000 pounds of phosphorus pentoxide per acre. So far as they went, results from the low nitrogen and potash series agreed with those of the high series in indicating a similar logarithmic curve; however, total growth averaged somewhat better and early growth much better with the lower nitrogen and potash levels for corresponding amounts of superphosphate.

Soluble phosphates in the plant increased greatly with increase in phosphate applications. In the two series with variable phosphate applications, this phosphorus content was strongly and positively correlated (correlation coefficient = 0.67 with a standard error of 0.11) with plant rejuvenation late in the season. The coefficient for the correlation of plant phosphate content and total yield was 0.72 with a standard error of 0.10.

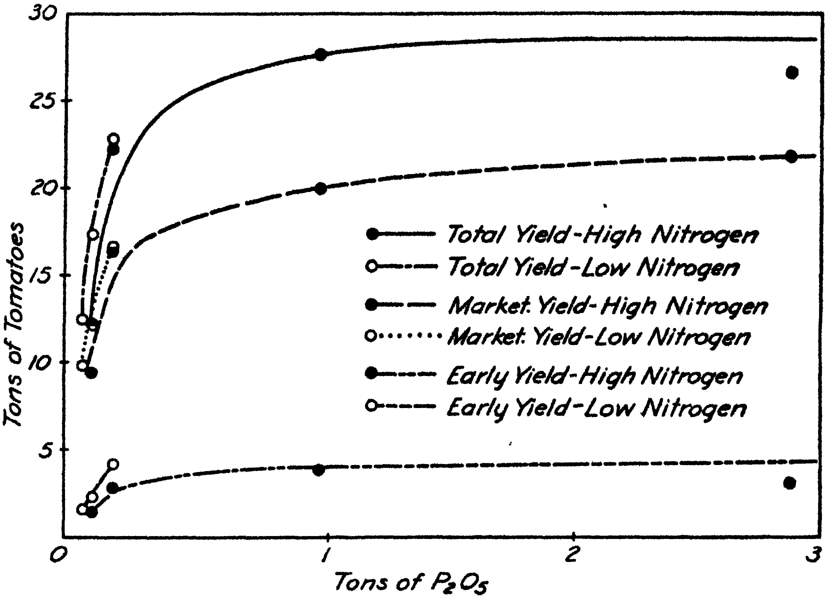

FIG. 1. Relation of yields to applications of phosphorus pentoxide. Curves are freehand, but it is obvious that true logarithmic curves would fit the data closely.

Soil acidity apparently affected the yields, although differences between the individual averages given are not significant.

It is doubtlessly due to the acidifying effect of sulfate of ammonia that the plots of the high nitrogen and potash series averaged significantly more acid than the plots of the low nitrogen and potash series. This difference in acidity may account for the somewhat lower yields of treatments 4 and 5 as compared with treatments 2 and 3.

Soil tests indicate a marked accumulation of readily available phosphate only where 1920 pounds or more of P_2O_5 per acre were applied. Tissue tests bear out the soil tests results in this respect. The fact should be borne in mind that, since the phosphate was mixed with only about half the soil of the plot, the rate of application on the area around the plant was actually about twice as great as that indicated in Table I.

EXPERIMENT ON CROSBY SILT LOAM

On May 21, 1942, 20 per cent superphosphate was applied to six plots on Crosby (light colored) silt loam at the rate of 10,000 pounds per acre. Plots were each 6 feet by 48. The fertilizer was spread over the surface of the ground and soon afterwards thoroughly mixed with the soil by use of a rotary tiller. Six corresponding plots received no superphosphate at this time, but were also thoroughly stirred with the tiller. After this initial application all plots were treated the same; all received fertilizer equivalent to about 30 pounds of nitrogen, 80 pounds of phosphorus pentoxide, and 60 pounds of potash on June 10, 12 days after the plants were set. This complete fertilizer was applied in bands about 4 inches deep and 6 inches from the bases of the plants. Thus, all plots received what is considered a large application of fertilizer in Indiana.

The variety used on the plots was a highly wilt resistant strain of Indiana Baltimore.

Soil samples were taken on all plots on September 30. The borings were made at points far enough from the rows that none of the fertilizer in the bands along the rows should have been included.

Harvesting began on August 6 and continued until September 22. Only tomatoes grading United States No. 1 or United States No. 2, according to the grades for canning tomatoes, were picked.

Rainfall on this experiment was extremely frequent and heavy during the 1942 season. Leaf diseases removed the older leaves by the time the first fruits were maturing. There was, however, a noticeably greater replacement of foliage on the heavily phosphated plots than on the checks. An extremely large crop of fruits set, but a large part of it was lost by the rotting which usually followed the many cases of severe fruit cracking.

The average yield for the plots without extra fertilizer was 6.4 tons per acre as against 9.0 tons for those with the very high applications of superphosphate. This increase of about 40 per cent is highly significant. There was every indication that had losses, due to fruit cracking and rotting been small, the same percentage increase in yield and a much bigger tonnage increase would have been obtained.

The average results of tissue tests made on August 20 were 5.8 on the high phosphate plots and 3.3 on the checks. These values are expressed in terms of the same arbitrary units as were used in summarizing the data for Kern silt loam. The difference is highly significant. Rapid extraction of the soil with a 0.1 per cent acetic acid solution removed an average of 166.0 pounds of P_2O_5 per acre from the high phosphate plots and 14.8 pounds from the checks which were fertilized with a complete formula. This difference is also highly significant. Thus plant tissue tests results, soil tests and plant response agree in indicating that the Crosby silt loam was not so deficient in phosphorus as the Kern silt loam.

There was no significant difference in soil acidity between the two sets of plots.

SUMMARY

Both the Kern silt loam and the Crosby silt loam used in the experiments here reported were deficient in phosphates and responded markedly to additions of phosphate far in excess of amounts usually applied in commercial practice.

Soil and plant tissue tests indicated that, when at least 2000 pounds of P_2O_5 per acre were applied, these soils, at the end of the season, still contained large quantities of available phosphates.

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Nitrogen, Phosphorus, and Potassium Nutrition of Tomatoes at Different Levels of Fertilizer Application and of Irrigation[1]

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THE present report is concerned with the nitrogen, phosphoric acid and potash nutrition of tomatoes grown under the irrigation conditions reported in an earlier paper (3).

MATERIALS AND METHODS

The nutritional status was determined by the method of foliar diagnosis (1).

Sampling:—Because the plants were not staked it was necessary to adopt the relay method of sampling. According to this procedure, if it is anticipated that it would be impossible to sample, periodically throughout the growth cycle, leaves of the rank selected because of premature senescence, a younger leaf, that is, a leaf of a higher rank is sampled at the same time as those of the rank taken earlier. Under such conditions the older leaf may be regarded as a later stage in the maturity of the younger. In the present experiment, the third leaf from the base of all plants was sampled on June 26, 1941, 23 days after planting. These were green and functioning normally on all plots. However, by the time of the second sampling on July 9 the third leaf from the base of plants on some of the plots of tier 3, the heavily irrigated tier, had drooped and when in contact with the soil were beginning to rot. These were not sampled. Since, therefore, it was apparent that by the time of the third sampling most of the leaves of the third rank would be in various stages of senescence, samples were taken also of the fifth leaves from the base at the same date (July 9) as those of second sampling of the third leaf from the base.

The next sampling of the fifth leaf was made on July 21. At this time all the leaves of rank three from the base had senesced on nearly all plots and even some of the fifth leaves from the base on plants growing on tier 3 were beginning to rot when in contact with the soil. It thus will be seen that only two samplings (June 20, July 9) of the third leaf were possible on all plots, and also only two samplings of the fifth leaf (July 9 and July 21).

At the next sampling on August 1, it was not possible to get healthy, functioning leaves below the thirteenth and even some of these were in various stages of senescence at this time (August 1). On this date, August 1, the fifteenth leaf from the base on all plants was still green and leaves of this rank were sampled on all plots. But 7 days later healthy leaves of this rank could not be obtained on all plots.

Irrigation:—Irrigation was practised whenever the moisture content of the soil of tier 1 was reduced in the top 6 inches of soil to 17 per cent and in that of tier 3 to 22 per cent. Irrigation was continued

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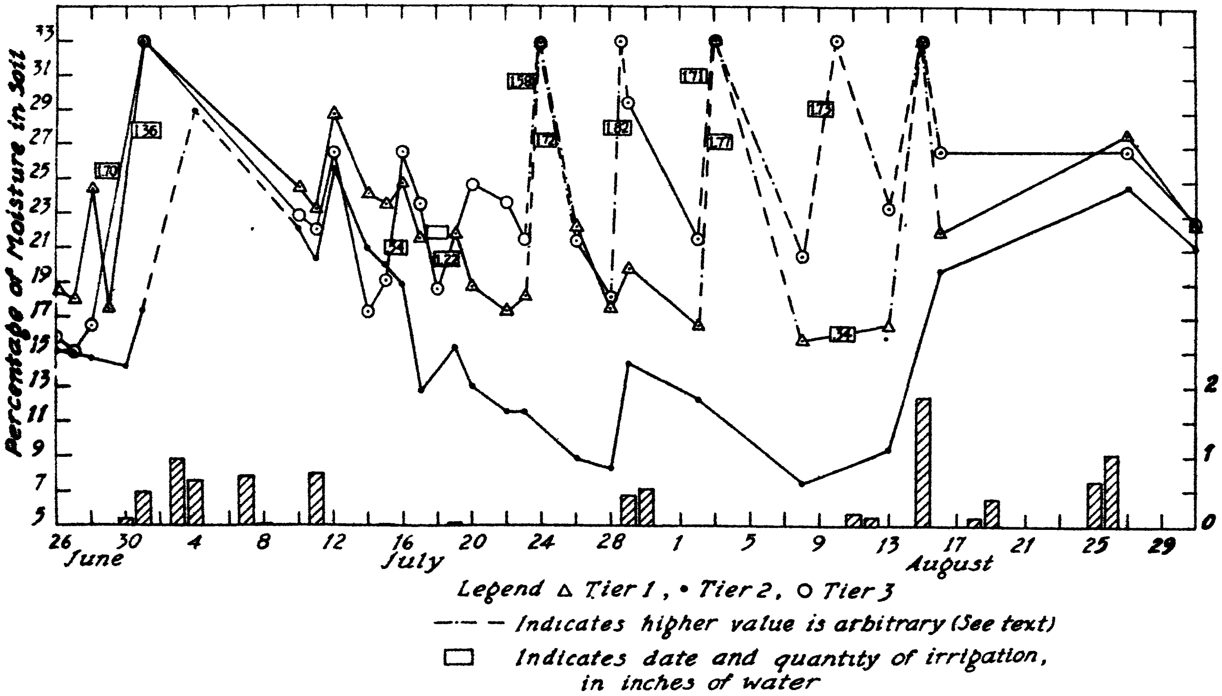


FIG. 1. Changes in the water content of the soil of the unirrigated tier 2, the medium irrigated tier 1, and the heavily irrigated tier 3.

to saturation of the soil to a depth of 6 inches in both tiers. Tier 2 was unirrigated.

Fertilizer:—The fertilizer was a 4–16–4 commercial grade applied at the rate of 0, 500, 1,000, and 2,000 pounds per acre respectively, broadcast and harrowed into the soil before plants were set into the plots.

Presentation of Data

Water Content of Soil:—The water content of the soil of the several tiers is shown in Fig. 1, together with the rainfall data. The blocked numerals on this graph show the actual amounts of irrigation water in inches applied at the dates given. Because of difficulty of getting over the plots when very wet, the values shown are arbitrary ones after irrigation of 1.5 inches or more.

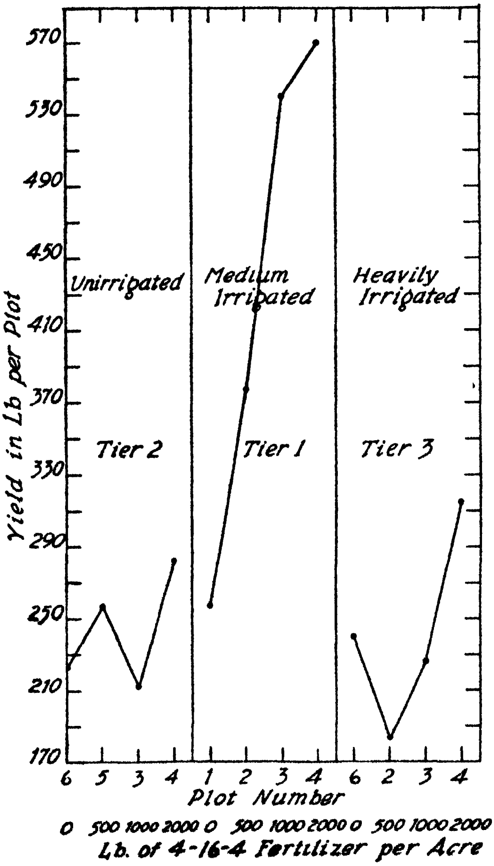
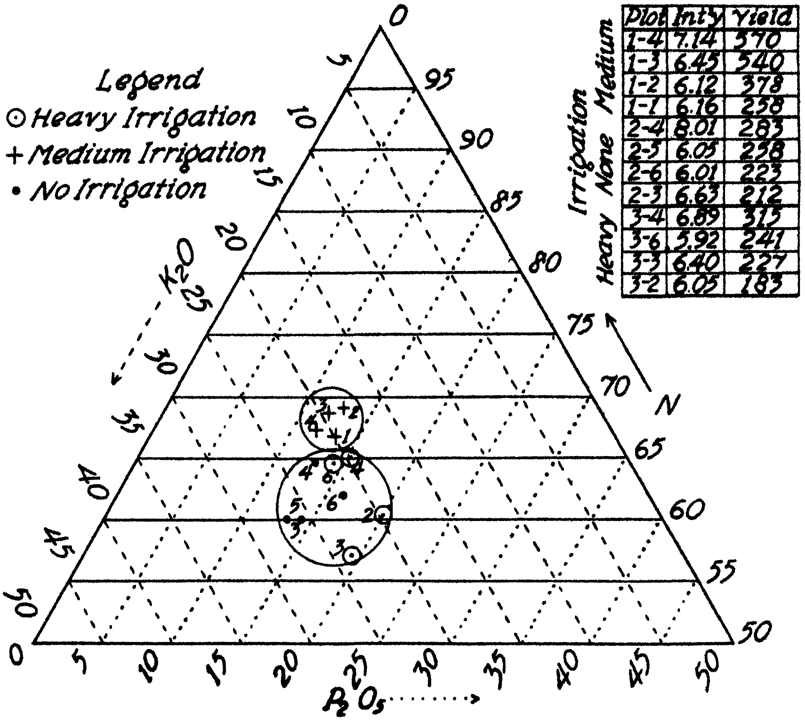


Fig. 2. Yields of fruit under the different conditions with respect to irrigation and fertilizer treatment. Ordinate, yields in pounds abscissa, amounts of 4–16–4 fertilizer per acre applied to plots indicated.

Yields:—Fig. 2 shows the yields from the different plots in the respective tiers. The values of the ordinates are pounds of fruit per plot. On the abscissa is indicated the quantity of fertilizer in pounds per acre applied to each plot.

Foliar Diagnosis Values: — The composition of the *NPK-units* at the periods indicated below are shown in trilinear coordinates in Figs. 3, 4, and 5. The composition of the *NPK-units* represents the equilibrium between N, P_2O_5, and K_2O at the moment of sampling the leaf of the rank considered. This unit is derived by converting the percentage composition for N, P_2O_5, and K_2O into milligram equivalents, and then finding the percentage each of these bears to the milligram equivalent total. Fractional values are avoided by multiplying the results by 100.

Fig. 3 shows the loci of the *NPK-units* of the



Irrigation	Plot	Int'y	Yield
Medium	1-4	7.14	370
	1-3	6.45	340
	1-2	6.12	378
	1-1	6.16	258
None	2-4	8.01	283
	2-5	6.05	258
	2-6	6.01	223
	2-3	6.63	212
Heavy	3-4	6.89	315
	3-6	5.92	241
	3-3	6.40	227
	3-2	6.05	183

FIG. 3. Intensities of nutrition (top right-hand corner) and loci of the *NPK-units* of the first sampling of the third leaf from the base. Samples taken on June 26

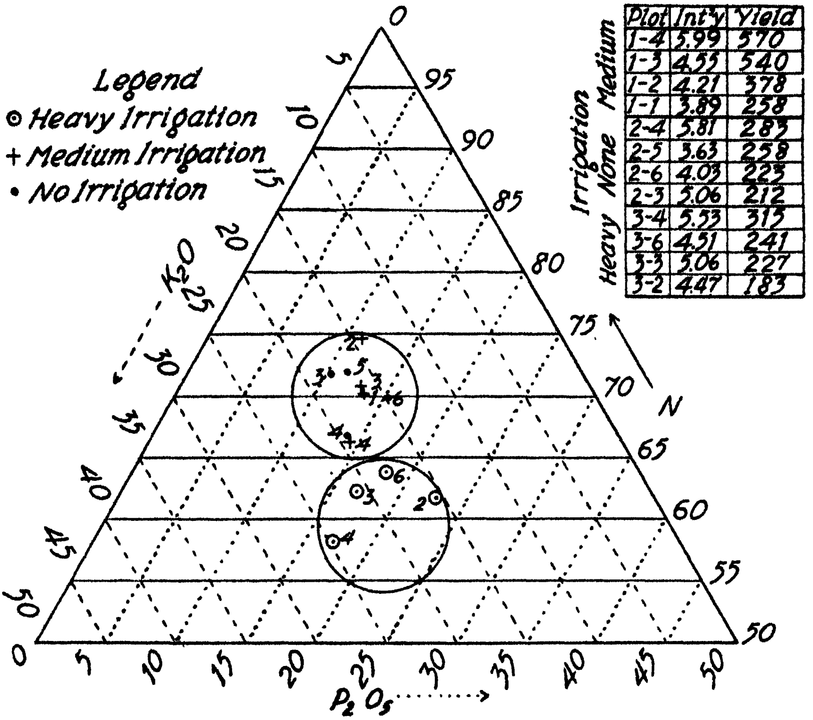
third leaf from the respective treatments on June 26, and consequently represents the equilibrium between N–P_2O_5–K_2O at the moment of sampling the leaf of this rank, and therefore before any of the tiers were irrigated.

Fig. 4 shows the loci of the *NPK-units* of the fifth leaf taken on July 9 and July 21. The data plotted are the means of the values at these periods of sampling and, consequently, represent the resultant equilibrium in the leaves of this rank up to the time when 1.71 inches of irrigation water had been applied to tier 1 and 3.46 inches to tier 3.

Fig. 5 shows the loci of the *NPK-units* of the fifteenth leaf from the several plots. Consequently, these represent the N–P_2O_5–K_2O equilibriums in the leaf of this rank, at a time when a total of 3.43 inches of irrigation water had been applied to the plots of tier 1, and 6.86 inches to tier 3.

DISCUSSIONS OF RESULTS

Yields:—Fig. 2 shows at a glance that only in the plots of the medium irrigated tier 1 is there a relationship between the quantity of fertilizer applied and the yields. The relationship is linear up to the second highest application, after which the curve flattens out, showing the operation of the law of diminishing returns.



Irrigation	Plot	Int'y	Yield
Medium	1-4	5.99	570
	1-3	4.55	540
	1-2	4.21	378
	1-1	3.89	258
None	2-4	5.81	283
	2-5	3.63	258
	2-6	4.03	223
	2-3	5.06	212
Heavy	3-4	5.53	313
	3-6	4.51	241
	3-3	5.06	227
	3-2	4.47	183

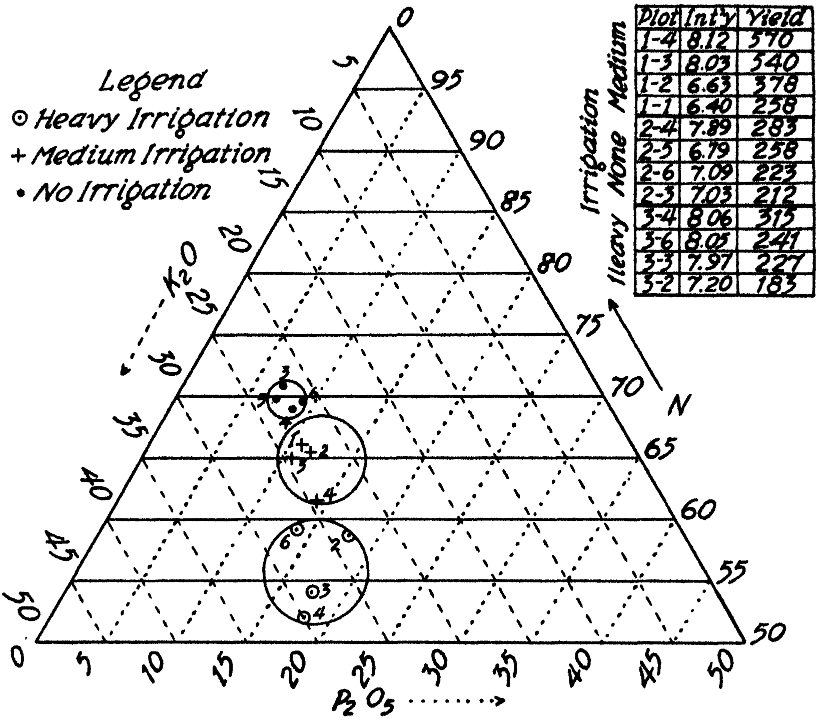
FIG. 4. Resultant intensities of nutrition (top right-hand corner) and loci of the resultant *NPK-units* of the fifth leaf from the base. Samples taken on July 9 and July 21.

In the plots of the unirrigated tier 2 a reversal in the direction of the graph occurs between the plot receiving the lowest application of fertilizer and that of plot 3 which received the next highest amount. The course of the yield curve then again reverses, its maximum being that of the plot which received the highest quantity of fertilizer.

In the heavily irrigated tier 3, the yields of the *fertilized* plots increase progressively with increase in the amount of fertilizer, but a sharp reversal of the curve takes place between the values for the ordinate of the unfertilized plot and that of the plot receiving the lowest quantity of fertilizer (500 pounds per acre), the yield of the latter accordingly being below that of the unfertilized plot.

The three plots with highest yields are the fertilized plots of the medium irrigated tier, the yields of which increase from 378 pounds in the unfertilized plot to 570 pounds in that receiving the highest application.

The yield of the unfertilized plot under medium irrigation is surpassed in the unirrigated and heavily irrigated tiers, only by the plots in these tiers receiving the largest amount (2,000 pounds per acre) of fertilizer. The increments are not very large. The higher yielding



Plot	Int'y	Yield
1-4	8.12	570
1-3	8.03	540
1-2	6.63	378
1-1	6.40	258
2-4	7.89	283
2-5	6.79	258
2-6	7.09	223
2-3	7.03	212
3-4	8.06	315
3-6	8.05	241
3-3	7.97	227
3-2	7.20	183

FIG. 5. Intensities of nutrition (top right-hand corner) and loci of the *NPK-units* of the fifteenth leaf from the base. Samples taken on August 1.

(315 pounds) of these two plots is well below that (378 pounds) of the plot in the medium irrigated tier receiving the smallest application.

The lowest yield (183 pounds) in this experiment given by plot 2 in the heavily irrigated tier corresponds to 9.2 tons of fruit per acre and that (570 pounds) given by the highest fertilized plot in the medium irrigated tier, to 28.7 tons of fruit.

Water Content of the Tiers:—The graph (Fig. 1) of the unirrigated tier is always below those of tier 1 and tier 3. Except during the rainy periods between July 1 and 17 and again between August 16 and 31, the water content of the unirrigated plots is below 15 per cent. During the dry period from July 18 to July 28 the water content of this tier dropped from 14 per cent to a low of 8.5 per cent; again during the period from July 30 to August 13 the water content of this unirrigated tier fluctuated between 14 and 7.5 per cent. Relative to the irrigated tiers, Fig. 1 shows that up to the time of the second sampling of the fifth leaf on July 21, the graph of the medium irrigated tier 1 is above that of the heavily irrigated tier 3 for the greater portion of the period from June 26 to July 21, notwithstanding the fact that by this time the heavily irrigated tier had received 3.46 inches of irrigation against 1.71 inches for tier 1. From July 21 on, however, the graph of tier 3 is above that of tier 1. No irrigation was necessary after August 10, by which time the heavily irrigated tier had received 10.3 inches of irrigation water and the medium irrigated tier 5.54 inches.

The graphs of the water content of the soils of tiers 1 and 3, between the periods when no irrigation was given, namely, from July 10 to July 14 and again from August 13 to August 31, indicate that tier 1 has a higher water retaining capacity than does tier 3.

Relation of Yields to the NPK Nutrition:—(a) *The Effect of Differential Irrigation on Equilibrium Drifts:*—A comparison of the graphs of Figs. 3, 4, and 5 shows that the drifts in the loci of the *NPK-units* of the unirrigated plots of tier 2 with progressive reduction of the soil water content is towards a relatively higher proportion of nitrogen, and a lower one of phosphoric acid and of potash.

The drift of the loci in plants from the medium irrigated plots is in the direction of a lower proportion of nitrogen and a higher one of phosphoric acid and of potash in the composition of the *NPK-unit.*

The drift of the equilibrium of the heavily irrigated plots is in the same direction as those of the medium irrigated tier; but in most plots the changes are relatively much greater.

By August 1, the date of the last leaf sampling, the loci of the plots of the several tiers are sharply segregated from one another as follows: (See Fig. 5 and Table I.)

TABLE I—PERCENTAGES OF N, P_2O_5, AND K_2O IN THE DRIED FOLIAGE, TOGETHER WITH THE INTENSITIES OF NUTRITION AND COMPOSITION OF THE NPK-UNITS IN THE FIFTEENTH LEAF

Tier	Plot	Amount 4-16-4 Fertilizer Per Acre (Lbs)	Yield of Ripe Fruit Per Plot (Lbs)	N (Per Cent)	P_2O_5 (Per Cent)	K_2O (Per Cent)	Intensity ($N+P_2O_5+K_2O$) (Per Cent)	Composition of NPK-unit		
								N	P_2O_5	K_2O
					Unirrigated					
2	4	2000	283	3.400	0.725	3.669	7.89	69.05	8.72	22.23
2	5	500	258	2.870	0.500	3.424	6.79	69.92	7.22	22.86
2	6	0	223	3.190	0.708	3.198	7.09	69.56	9.14	21.50
2	3	1000	212	3.150	0.550	3.327	7.03	70.49	7.29	22.21
					Medium Irrigation					
1	4	2000	570	2.980	1.141	3.995	8.12	61.56	14.24	24.20
1	3	1000	540	3.190	0.870	3.972	8.03	65.23	10.54	24.23
1	2	500	378	2.700	0.816	3.114	6.63	65.65	11.76	22.59
1	1	0	258	2.630	0.725	3.049	6.40	66.26	10.82	22.92
					Heavy Irrigation					
3	4	2000	315	2.070	1.225	4.761	8.06	52.20	18.10	29.70
3	6	0	241	2.760	1.100	4.186	8.05	59.22	13.99	26.79
3	3	1000	227	2.420	1.325	4.224	7.97	54.20	17.58	28.22
3	2	500	183	2.540	1.300	3.359	7.20	58.86	17.86	23.28

Group 1. The unirrigated plots of which the loci are characterized by the highest values for nitrogen and the lowest values for phosphoric acid.

Group 2. The heavily irrigated plots having the lowest values for nitrogen and the highest values for potash and also (the unfertilized plot excepted) for phosphoric acid.

Group 3. The plots of the medium irrigated tier of which the values of the loci are intermediate between those of groups 1 and 2.

These drifts indicate the effect of the differences in water supply on the *quality* factor of nutrition, that is, on the proportions of these components. The trend of the drifts is the same for comparable plots on the respective tiers. Thus, the data show that the differences in yields between similarly fertilized plots are related to the drifts in such a way that the lower yields of the unirrigated and heavily irrigated plots are associated with disequilibriums in the nutrition of the plants growing on the unirrigated tier characterized by too high nitrogen and too low phosphoric acid; whereas, those on the heavily irrigated tier are too low in nitrogen and too high in phosphoric acid and potash.

(b) *The Effect of Differential Fertilization Under Each System of Irrigation:*—Except among the plots of the medium irrigated tier, the relationship of the NPK-nutrition to yields of the several plots within a particular tier is less evident. Inasmuch as the quantity of fertilizer applied to the plots of a tier progressively increases, a relationship would exist between the intensity (internal concentration) and the amount of fertilizer applied (external concentration) *provided that the differences in development are due solely to the differences in fertilizer applied.* And, in fact, this relationship holds throughout the cycle among the plots of the medium irrigated tier 1, but irregularities occur in the plots of the unirrigated and heavily irrigated tiers respectively.

Of the unirrigated plots, that receiving the highest application of fertilizer does have the highest intensity throughout the cycle. This holds for the plot receiving the highest quantity of fertilizer in the heavily irrigated tier also.

And, again, except in the plots of the medium irrigated tier, there exists no regular relationship between yields and the *quality* factor of nutrition. In respect to the fertilized plots of the medium irrigated tier, the higher the yield the nearer is the locus of the *NPK-unit* to that of the optimum. This holds throughout the cycle, consideration being given to the fact that the relatively good equilibrium of the unfertilized plot cannot, however, compensate for its low intensity.

The causal factors of irregularities between the NPK-nutrition and yields of plots in the unirrigated and heavily irrigated tiers may be sought. In the plots of the unirrigated tier, field conditions necessitating the adoption of the relay method of sampling may be the interfering factors. Actually, a leaf of lower rank can be regarded as a later stage in the physiology of one of higher rank only in case no abrupt discontinuous changes occur in the external environment. In the unirrigated plots the water content of the soil sank at periods to extremely low levels (for example 8.0 per cent), *when, consequently, water and not mineral elements was the limiting factor.*

The cause of irregularity in the nutrition of the plots of the heavily irrigated tier is principally the result of a lack of uniformity with respect to the water content of the soil of the plots as the result of the inability to control the water supply so as to affect equal distribution over all the plots in the system of irrigation used. The nature of these inequalities insofar as they affect the NPK-nutrition can be demonstrated very readily from an examination of the course of nutrition, during the cycle, of the individual elements taken separately. Details need not be considered in this paper. The inequality is particularly evident in the case of nitrogen. For example, in the third leaf, the percentage of nitrogen in the unfertilized plot is greater than in that receiving the lowest application of fertilizer and that of the latter is greater than that from the next higher application. Irregularities of this type appear with respect to both nitrogen and phosphoric acid in the fifth leaf also. Water logging may be a contributing factor also in causing abnormal CO_2/O_2 conditions in the soil.

(c) *Foliar Diagnosis Versus Statistical Methods:*—In view of these results one may be permitted to examine the intrinsic significance of field experiments, the plot arrangement of which is alleged (by statistical analysis) to reveal its own error. Apart from the fact that the theory of probabilities as applied to small numbers is from a logical standpoint invalid, the objection may be urged that in the statistical manipulation a specific property possessed by the whole or any part of a living organism is submerged into an abstract quantity — a procedure opposed to the whole spirit of biology.

It is surely more in keeping with the scientific method, to lay emphasis on increasing the number of observations made during the growth cycle on a particular plot rather than in increasing the number of plots (2).

Even the large number of observations made in this experiment have, as we have seen, not sufficed to identify completely in all cases the causal factors giving rise to the different yields. How then can observations solely with respect to yields at maturity suffice, by whatever process of statistical manipulation to which they may be subjected?

SUMMARY

The relationships between yields and nutrition of tomatoes grown under different levels of irrigation and with varying quantities of a complete fertilizer are examined by the method of foliar diagnosis. The yields of fruit range from a maximum of 570 pounds received from the most heavily fertilized plot (2,000 pounds 4–16–4 fertilizer per acre) under medium irrigation to a minimum of 183 pounds from the least fertilized (500 pounds per acre), heavily irrigated plot. These yields correspond to 28.7 tons and 9.2 tons per acre respectively.

For the greater portion of the early part of the growth cycle the water content of the soil of the medium irrigated tier is above that of the heavily irrigated tier; but the condition is reversed afterwards. The water content of the unirrigated tier is reduced to very low levels during dry periods and at two sampling periods sank to 8 per cent.

As the differences increase with respect to irrigation supplied, the plants on the respective tiers tend to become more differentiated with respect to *quality* factor of nutrition. These differences are described and are shown in trilinear co-ordinate diagrams. The relation of yields to the NPK-nutrition of differently fertilized plots in the respective tiers also is described and the causes of certain irregularities are examined.

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Comparison of the Nutrition of Greenhouse and Field Grown Tomatoes with Respect to the Fertilizer Elements[1]

By Walter Thomas and Warren B. Mack, *Pennsylvania Agricultural Experiment Station, State College, Penn.*

THE evaluation of the mineral nutrition is based upon the fundamental principles of foliar diagnosis (1). Comparison is made first between similarly fertilized tomatoes grown in one case in the greenhouse (2) and in the other in the field (3). In both comparisons, a 4–16–4 commercial fertilizer was used at the rate of 2000 pounds per acre without manure, broadcast and worked into the upper 3 inches of the soil. In the greenhouse experiment there were 12 plants to a plot of 46 square feet and in the field 30 plants to a plot of 432 square feet.

The values obtained for the *intensity of nutrition* and the composition of the *NPK-unit* of the fifth leaf from the base in all cases are shown in Table I.

TABLE I—INTENSITIES AND NPK-UNITS OF THE FIFTH LEAF FROM THE BASE OF SIMILARLY FERTILIZED PLOTS (2000 POUNDS PER ACRE OF A 4–16–4 FERTILIZER)

Location	Plot No.	Intensity (Per Cent $N+P_2O_5+K_2O$)	Composition of NPK-Unit			Yield in Pounds	
			N	P_2O_5	K_2O	Plot	Sq Ft
Greenhouse. . . .	2R	6.1	71.0	21.2	7.8	113.8	2.47
Field .	1-4	6.0	66.5	14.0	19.5	570.4	1.32

On an equal area basis, therefore, the yield of fruit is 87 per cent greater in the spring greenhouse crop than in the field. Although little difference exists in the *quantity* factor of nutrition under the two conditions, a marked difference is evident in the *quality* factor. In the greenhouse plants the greater yield is associated with much higher values for nitrogen and phosphoric acid in the composition of the *NPK-unit* and much lower values for potash compared with these in the field grown plants.

It is also of interest to compare the nutrition of the lowest yielding plots in the greenhouse and field respectively, as shown in Table II.

TABLE II—INTENSITIES AND NPK-UNITS OF THE FIFTH LEAF FROM THE BASE OF THE LOWEST YIELDING PLOTS

Location	Plot No.	Fertilizer	Intensity	Composition of NPK-Unit			Yield Per Sq Ft (Pounds)
Greenhouse.	11R	PK*	4.8	60.5	27.1	12.4	0.37
Field.	3-2	NPK*	4.5	61.8	22.7	15.5	0.42

*Field application was 500 pounds of 4–16–4 fertilizer per acre, greenhouse application equivalent to 2,000 pounds of 0–16–4 per acre.

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[1] Authorized for publication on November 10, 1942, as paper No. 1144 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

Under both conditions of growth, low yields are accompanied by low values for the intensities, in each case brought about by low values for nitrogen in the *NPK-unit*.

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The Value of Filter Press Cake as a Fertilizer for Vegetable Crops, Preliminary Trials with Tomatoes and Cucumbers

By ARTURO RIOLLANO, *University of Puerto Rico, Isabela, P. R.*

FILTER press cake is normally a by-product from the sugar mills of Puerto Rico. In many cases the disposal of this refuse is a sort of a problem since its dumping is rather costly. In other cases, the filter press cake is used for fertilizing the sugar cane plantations where apparently good results have been obtained with it when utilized as a substitute for chemical fertilizers. Some sugar mills have enormous quantities of filter press cake that have been accumulated for several years near the premises of the factory. In one of these sugar mills visited by the author, the filter press cake dump covered an area of approximately 4 acres in extent and was 6 to 8 feet deep. Dumping in that place had been going on for the last 10 years.

Samples of filter press cake from this dump were taken at various depths, namely: first 12 inches, 12 to 24 inches, and 24 to 36 inches. For each depth, eight samples from different places of the dump were taken. Analyses[1] were made from these samples through the courtesy of Dr. J. A. Bonnet, Chief of the Division of Soils, as shown in Table I.

TABLE I—ANALYSES OF FILTER PRESS CAKE

Samples	Depth (Inches)	Original Moisture Content	pH	Air Dry Samples				
				H_2O (Per Cent)	P_2O_5 (Per Cent)		Available K_2O (Per Cent)	Total N (Per Cent)
					Total	Available		
1	0 to 12	54.45	5.5	12.76	3.83	0.59	0.02	3.13
2	12 to 24	26.24	6.5	12.04	2 63	0.66	0.08	2.65
3	24 to 36	29.83	6.7	12.96	3.49	0.50	0.17	2.72
Average						0.58	0.09	2 83

As may be readily seen in these analyses, the water content of filter press cake is rather high, varying from 26.24 to 54.45 per cent in the samples taken. The air dry samples, however, were reduced to a uniform moisture content varying only from 12.04 to 12.96 per cent. The analyses for food nutrients, total and available, were made on basis of these air dry samples. Verbal information was obtained regarding the availability of the total nitrogen reported, to the effect that for practical purposes all this nitrogen was in available form. For the purpose of our trials with vegetable crops, we are considering only as important the following averages of available food nutrients in air dry samples of filter press cake: nitrogen 2.83 per cent, P_2O_5 .58 per cent, and K_2O .09 per cent. The amount of potash contained is so small that it may be considered as negligible. In fact, in other samples that the author had sent for analysis in previous year, the potash content had been reported in the form of traces.

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[1] By law, nitrogen in fertilizer analyses in Puerto Rico must be expressed as NH_3.

TRIAL WITH TOMATOES

The first preliminary trial with filter press cake was established at the Isabela Experimental Substation with tomatoes, variety "Marglobe", in the type of soil known as Coto clay. Bonnet (1) has described the properties of this type of soil of which there are some 7,000 acres located at the northwestern section of the island. Two treatments were tested, namely, one where filter press cake in its natural state was applied at the rate of 12 tons per acre plus 1,000 pounds of chemical fertilizer 8–10–15 and the other, where 1,000 pounds of the last named fertilizer were applied alone. The filter press cake as well as the chemical fertilizer were applied in the furrow about 10 days before transplanting in both cases. Forty plants were used in each plot which measured 20 by 22 feet or approximately 1/100th acre. Each treatment was replicated eight times. The soil was prepared to be irrigated by the surface irrigation system commonly known as the Hawaii system. Upon harvesting the fruit was classified as follows: large, weighing above .3 pound; medium, weighing .2 to .3 pound; small, weighing less than .2 pound; and culls, or unmarketable fruit. Weighings for each treatment were recorded in pounds and tenths of pounds. A total of seven different pickings were made in this trial.

RESULTS

The results of this preliminary trial are presented in detail in Table II. Significance of differences in mean yields has been determined by calculating the odds for the z values of "Student's table" as modified by Love (2).

TABLE II—THE EFFECT OF FILTER PRESS CAKE IN THE YIELD OF TOMATOES (MEAN YIELD IN HUNDREDWEIGHTS PER ACRE)

Classification of Fruit Yield	Treatment A 12 Tons Filter Press Cake Plus 1000 Pounds Fertilizer 8–10–15 Per Acre (Cwts)	Treatment B 1000 Pounds Fertilizer 8–10–15 Per Acre (Cwts)	Increase (Per Cent)	Odds
Large, above .3 pounds	69.9	58.5	19.5	18:1
Medium, .2 to .3 pounds	70.6	56.4	25.2	216:1
Small, less than .2 pounds	16.8	15.6	7.7	2:1
Culls, unmarketable	21.3	15.7	35.6	151:1
Marketable fruit	157.3	130.5	20.5	48:1
Total, all classes	178.6	146.2	22.2	32:1

As may be observed in Table II, there was always a tendency to increase yield when filter press cake was applied to the soil. However, summing up these results in the most practical way, that is considering mean yields of marketable fruit, it may be seen that this increase amounted significantly to 20.5 per cent. In other words, the application of 12 tons of filter press cake was responsible for a significant increase in yield of 1.34 tons of marketable tomatoes per acre. Further work with tomatoes had to be suspended due to a heavy mosaic infection appearing in the region.

TRIAL WITH CUCUMBERS

Upon failing to continue the work with tomatoes due to a heavy infection of mosaic, a more elaborate test with filter press cake was established in the same type of soil with the variety of cucumbers known as "Early Fortune". Though compost manure is rather scarce in Puerto Rico and is seldom used with vegetable crops, it was also included in this test as a matter of comparison. Check plots without any fertilizing matter were not incorporated in the test because in previous trials conducted by the author these had resulted in complete crop failures. Twenty tons of filter press cake per acre or 20 tons of compost manure were added to the soil with various combinations of 200 pounds of NH_3 derived from sulphate of amonia, 200 pounds P_2O_5 from superphosphate, and 200 pounds of K_2O from sulphate of potash. Filter press cake and compost manure were also applied separately and alone without any chemical fertilizer. In all, 14 treatments with seven replicates each in randomized blocks were included in this trial.

Plots measured 1/80th of an acre and there were 107 cucumber plants in each plot. The soil was prepared in such a way as to facilitate surface irrigation whenever necessary. The different fertilizing materials were applied in the furrow 12 days before planting cucumbers. A total of 12 pickings were made during a harvesting period of 29 days. Fruit was classified according to the United States standards and weighings were recorded in pounds and tenths of pounds.

RESULTS

The results of this trial are shown in detail in Table III. Though fruit was classified according to United States standards, results have been presented in total yield of all classes because this seems to be the best criterium for making comparisons. Yields from each treatment have been expressed in the form of hundredweights per acre. Significance of results has been determined by Fisher's (3) method of statistical analysis.

The 14 different treatments are subject to numerous comparisons, but a few will suffice to demonstrate the high fertilizing value of filter press cake for cucumbers. Upon comparing treatments 14 and 4 it can be observed that an application of 20 tons of filter press cake alone produced 118 hundredweights of cucumbers per acre, while the application of the complete chemical fertilizing produced 116 hundredweights of fruit. Thus, it seems that the filter press cake can be a reliable substitute for chemical fertilizers. Furthermore, when the filter press cake and the complete chemical fertilizer were applied together, the yield was augmented significantly to 140 hundredweights per acre as shown in treatment 12. In all cases filter press cake plus chemical fertilizers, complete or incomplete, caused an increase in yield when compared with complete and incomplete fertilizers alone. Compost manure, in general, ranked lower than filter press cake as an organic fertilizer.

Incidentally, a comparison of treatments 1, 2, 3 and 4 gives a strong

TABLE III—THE FERTILIZING VALUE OF FILTER PRESS CAKE FOR CUCUMBERS (YIELDS ON BASIS OF ALL CLASSES OF FRUIT)

Number of Treatment	Filter Press Cake (Tons Per acre)	Compost Manure (Tons Per Acre)	NH_3 (Pounds Per Acre)	P_2O_5 (Pounds Per Acre)	K_2O (Pounds Per Acre)	Mean Yield (Cwts Per Acre)*
12	20	0	200	200	200	140
9	20	0	200	200	0	134
5	0	20	200	200	0	126
11	20	0	0	200	200	126
10	20	0	200	0	200	125
14	20	0	0	0	0	118
4	0	0	200	200	200	116
7	0	20	0	200	200	116
8	0	20	200	200	200	115
6	0	20	200	0	200	109
13	0	20	0	0	0	107
1	0	0	200	200	0	103
2	0	0	200	0	200	80
3	0	0	0	200	200	78

*Differences in yield greater than 22 2 are significant with odds 19:1.

indication that the type of soil Coto clay is markedly deficient in available NH_3 and P_2O_5. However, the requirements for K_2O are not high. In fact, the next highest yield or probably the most profitable application for the grower, was obtained with treatment 9, when 20 tons of filter press cake, 200 pounds NH_3 and 200 pounds P_2O_5 were applied. This did not differ significantly from the highest yield obtained in treatment 12 where the filter press cake was applied with the complete chemical fertilizer. Bonnet (1) has also shown similar results with eggplants and cucumbers in regards to availability of K_2O in this type of soil.

SUMMARY

Filter press cake, a refuse from sugar mills in Puerto Rico can be used advantageously for fertilizing tomatoes and cucumbers grown in the soil type Coto clay. When applied to the furrow at the rate of 12 tons per acre plus 1,000 pounds of 8–10–15 fertilizer, it caused a significant increase in yield of marketable tomatoes amounting to 20.5 per cent over the treatment where 8–10–15 chemical fertilizer had been applied alone at the rate of 1,000 pounds per acre.

When 20 tons of filter press cake were applied to the furrow alone and with different complete or incomplete chemical fertilizers, significant increases in yield of cucumbers were also observed. The yield obtained with 20 tons of filter press cake alone was equivalent to the yield obtained with a complete fertilizer having 200 pounds NH_3, 200 pounds P_2O_5 and 200 pounds K_2O. Results seem to indicate that the most profitable treatment tried would be 20 tons of filter press cake plus 200 pounds of NH_3 and 200 pounds of P_2O_5.

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Increasing Tomato Yields by Interplanting

By M. M. PARKER, *Virginia Truck Experiment Station, Norfolk, Va.*

THE introduction of tomato varieties with distinct habits of earliness and size of plant offer in some tomato sections the possibility of utilizing these characteristics in a complementary way rather than in the competitive one in which they are usually considered. The application of the principles involved would be primarily in those regions which could use both an early tomato for market purposes and a long season one for processing; or where it is desired to prolong the bearing season over a long period of time, or to obtain increased yields from a given area of ground. The success of the operation depends upon the proper selection of varieties; the subordination of one variety to another, and the alternate, orderly spacing of the two varieties in the same row.

PROCEDURE

The Rutgers tomato was used as the principal variety. It was planted 4 feet apart in the row and 5 feet between rows. This variety constitutes the principal one in eastern Virginia where large plantings are made mainly for processing. The plant ultimately reaches a very large size, is rather late and the length of its bearing season is limited in most cases only by climatic conditions. The subordinate variety was selected from the early maturing, determinate growth type. The Victor tomato which may be considered representative of this group was selected for the complementary variety. It produces a large number of very early fruits, bears for only a limited period of time and the ultimate size of the plant is small. It was interplanted in the row midway between Rutgers plants, spaced 4 feet apart which resulted in one Rutgers plant and then a Victor evenly spaced 2 feet apart in the row.

A similar planting was made with the Marglobe variety whose habits of growth are very much like the Rutgers. Control rows of Rutgers, Marglobe and Victor plants were spaced 4 feet apart in the row and 5 feet between rows for the first two varieties and 2 feet apart in the row and 5 feet between rows for the Victory variety. All varieties were fertilized at the rate of 1000 pounds per acre with a 3–12–6 fertilizer.

Throughout the early part of the season conditions were favorable for growth but before the fruit had begun to ripen a deficiency of soil moisture greatly reduced the total yield.

RESULTS

One of the principal characteristics of the selected varieties which would tend to make the interplanting of distinct kinds of tomatoes a commercial possibility is illustrated in Table I. In this table the cumulative percentage of tomatoes harvested at given dates is shown both for the interplanted and the separate varieties. The table shows that the Victor tomato was considerably earlier in producing ripe fruit and that it had completed the greater proportion of its yield long

TABLE I—THE CUMULATIVE PERCENTAGE OF TOMATOES HARVESTED AT GIVEN DATES

Variety and Planting	July				August		
	10	15	21	27	4	12	18
Victor (between Rutgers)	5.6	23.3	48.3	80.1	99.6	—	—
Rutgers (between Victor)	0.8	1.9	8.9	27.8	51.2	88.2	100.0
Victor (alone) plants 2 feet apart	4.0	21.7	42.3	80.3	92.9	97.6	100.0
Rutgers (alone)	0.1	1.0	5.2	26.7	46.4	81.9	100.0
Marglobe (alone)	0.0	2.2	8.7	23.4	52.2	82.4	100.0
Marglobe (between Victor)	1.9	6.2	14.9	32.6	61.2	87.0	100.0
Victor (between Marglobe)	4.9	25.4	50.4	87.5	100.0	—	—

before either the Rutgers or the Marglobe had begun to bear heavily. Thus, on the second harvest date the Victor interplanted with the Rutgers had produced 23 per cent of its total yield while on the same date the Rutgers variety had produced only about 2 per cent. Where these two varieties were planted in separate rows this same relative degree of maturity was maintained. The Victor produced nearly 22 per cent of its total yield and the Rutgers only 1 per cent. Interplanting therefore, had little if any effect upon the rate of maturity of these varieties, but within the same variety the rate of maturity was consistently increased where they were interplanted. After the fourth harvest the Victor had produced 89 per cent of its total yield and the plants had begun to die. The Rutgers at this same time had produced only slightly more than one-fourth of its total yield but the vines were in a vigorously growing condition and were in a position to use the space in the row left by the dead Victor plants. The success of interplanting tomatoes depends upon having one variety mature all of its fruit early in the season in order that the larger, later variety may utilize the space left vacant by the death of the subordinate variety.

The trend in the behavior of the Marglobe and Victor interplanting was similar to that of the Rutgers and Victor interplanting in regard to the rate of maturity. The Marglobe has characteristics of growth closely resembling that of the Rutgers and the results obtained from it in the interplanting were nearly identical with those from Rutgers.

EFFECT ON YIELD

The total yield of tomatoes from both the interplanted varieties and the individual ones spaced the regular commercial distance is given

TABLE II—YIELD (TONS PER ACRE) INTERPLANTED VARIETIES

Planting	Victor	Rutgers	Marglobe	Total Yield	
				Tons	Per Cent Increase
(Interplanting)	2.8	5.9	—	8.7	Over Rutgers alone 61 Over Victor alone 30
(Interplanting)	2.9	—	5.9	8.8	Over Marglobe alone 46 Over Victor alone 31
Straight planting	6.7	—	—	6.7	—
Straight planting	—	5.4	—	5.4	—
Straight planting	—	—	6.0	6.0	—

1.2 tons required for significance.

in Table II. It will be seen that both the Rutgers and the Marglobe gave just as large a yield when interplanted with the Victor as they did when planted by themselves in individual rows. Therefore, any tomatoes produced by Victor when interplanted with either the Rutgers or the Marglobe could be considered as yield increases due solely to this method of planting. Since the Victor variety produced nearly 3 tons of tomatoes per acre when interplanted with either the Rutgers or the Marglobe the increase in total yield was 61 per cent greater than that from the Rutgers planting and 46 per cent larger than that from the Marglobe. Where the Victor variety was planted by itself 2 feet apart in the row its yield was only about 75 per cent as large as the total yields obtained from the interplantings.

Since the Victor variety produced most of its fruit very early in the season and the other two varieties comparatively late, the increased yields were obtained over a long period of time which lengthened the harvest season and increased the marketing period principally during the earlier part of the season.

EFFECT ON QUALITY

A large number of tomatoes are usually lost from fruit rots in the immature stage following periods of hot, sultry weather. Those varieties that produce a large amount of foliage which shades the fruit seem to suffer fewer losses from fruit rot than do the more sparsely foliaged types. The interplanting of a large vined, densely foliated variety and a small growing sparsely foliated one would tend to prevent sunscald and rotting of the fruit during hot weather since the larger vined type when planted 2 feet from the smaller one would spread over it and help to shade its fruit. The amount of sun scald on the fruit from the interplanted tomatoes was not seriously objectionable. Where the Victor variety was interplanted with the Rutgers, the former had 9 per cent less rot by weight than it did when planted by itself. The Rutgers variety lost 4 per cent less from rot when interplanted than when planted alone. A similar relationship in the amount of rot existed in the Marglobe and Victor interplantings. The Victor showed 5 per cent less rot when interplanted with Marglobe and the Marglobe 5 per cent less than when planted alone.

SUMMARY

Interplantings of Victor and Rutgers varieties and Victor and Marglobe varieties resulted in yield increases more than 60 per cent larger than that obtained from the Rutgers variety alone and 46 per cent larger than that obtained from the Marglobe variety alone. The harvesting period extended over a greater length of time principally during the early part of the season. Losses due to rot of immature fruit were somewhat reduced by interplanting.

Experiments With Lima Beans[1]

By WILLIAM H. LACHMAN and GRANT B. SNYDER, *Massachusetts State College, Amherst, Mass.*

THE culture of bush lima beans is not a widespread enterprise in the Northern States chiefly because of the uncertainty of success with the crop. Under certain conditions yields are satisfactory and the cultivation of lima beans is a profitable business but many horticulturists obtain indifferent yields and failure often results from reasons which are either obscure or unknown. The plants often make a robust growth and blossom freely but they fail to produce well.

It has been shown by Hester (1) that the acidity of the soil has a profound influence on the growth of lima beans. Other workers (6, 8) have noted that the ratio of the critical elements in the commercial fertilizer exerted a significant effect on yields. Low percentages of germination with a poor stand of plants resulted in low yields. The length of the growing season also has been stressed (3, 7) as an important factor which influences the yield of lima beans. Considerable attention has been given to the problem of correct plant spacing and while there is some evidence (4, 9) that close planting is associated with high yields, the data of Mahoney *et al.* (3) is conflicting.

The experiments herein described were pursued in an effort to observe the influence of the foregoing factors on the yield of beans under conditions similar to those that prevailed at Amherst, Massachusetts, during the summers of 1941 and 1942. The conditions for the growth of vegetables during these two years would be classed as ideal, as there were frequent and timely rains which provided excellent moisture conditions and other factors associated with weather were nearly optimum. The soil of the plots is classed as a Merrimac fine, sandy loam with a pH of 5.6 and is in a high state of fertility. A good strain of Fordhook bush lima was used and the planting and cultural conditions were as near optimum as was possible.

In 1941 four plots were laid out on which ground limestone was applied at the rates of ½ ton, 1 ton, and 2 tons per acre with the fourth plot remaining as a check. These plots were replicated four times. The plants grew very well but growth differences were not visible at any time. The pods were harvested until frost killed the plants and when the data were analyzed by statistical treatment it was found that the differences in yields obtained were not significant as they gave an F value of 2.48 whereas a value of 3.86 is required at the .05 level.

In 1941 and 1942 plots were laid out in which different ratios of commercial fertilizer were applied. Fifteen hundred pounds each of 5–8–7, 10–8–7, 5–14–7 and 5–8–14 were broadcast before the seed was planted. The plots were replicated four times in 1941 and three times in 1942. When the yield data were subjected to statistical treatment it was found that none of the differences in yields were significant. It was expected that extra phosphorus might possibly increase the yield under most conditions but the soil in the plots was an old market garden soil with a large reserve of phosphates present.

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[1] Contribution No. 467 of the Massachusetts Agricultural Experiment Station.

A number of authorities recommend the planting of lima bean seed with the "eye" down to obtain a better stand of plants. A comparison was made of the two methods of planting, "eye" up versus "eye" down, wherein 100 seed of each treatment were planted and they were replicated seven times. The "eye" down treatment germinated 3.1 per cent better than "eye" up with odds of 19 to 1. Another test was made in the greenhouse of the two methods of planting under optimum conditions with both methods of planting each replicated ten times. The "eye" down planting germinated 5.3 per cent better than the "eye" up treatment with odds of better than 99 to 1. This method of planting precludes the use of machinery so would not be practical in large plantings.

There has been some controversy concerning the influence of plant spacing on the yield of lima beans so the plantings were thinned at different rates to test the relation between the spacing of the plants and yield. The rows were spaced 3 feet apart in all of the plantings. The plant spacing in some of the rows averaged as close as 3½ inches and the spacing in the rows was increased until some of them averaged as great as 15 inches between each plant. It was found that the 1942 data gave a correlation coefficient of .29 and the 1941 data a coefficient of .53. Although an "r" value of .29 is of questionable significance, an "r" value of .53 is certainly noteworthy because this indicates that in 1941 27 per cent of the variation in yield was associated with the spacing of the plants. In general, these results are corroborated by the work of Matthews (4) and White-Stevens and Hartman (9).

The germination, and hence the final stand, of many crops is improved by use of seed protectants. Spergon is a protectant that is applied as a dust to the seed at the rate of about 2 ounces per bushel of seed. Six lots of seed, 100 seed in each lot, were treated with Spergon in 1941 and it was found that these lots averaged 19.7 per cent better in germination than the respective check plantings with odds of better than 99 to 1. This finding has been substantiated by the work of McNew (5).

Lima beans are generally regarded as a long-season crop and many northern growers feel that their growing season is too short for the proper growth and development of lima beans. The season is extended with many crops by starting them in the greenhouse and transplanting in the open after the weather has warmed up sufficiently in the spring. Beans, however, have been classified by Loomis (2) as, "a crop not successfully transplanted by the usual methods". On May 16 several seeds were planted in 3-inch paper pots in the greenhouse. After the seeds germinated, the plants were thinned to one plant per pot and were transplanted to the field on June 4. The paper pots were carefully removed from around the ball of soil at the time of transplanting because the plants establish themselves much faster in the soil, as shown from previous experience. The check plots were seeded in the field on June 4 and each treatment was replicated five times.

It is a noteworthy fact that the plots of beans that were started indoors made a very quick and vigorous growth as compared with the plots that were seeded directly in the field. The first harvest from the transplanted plots was made 19 days before that from the directly seeded plots and the total yield from the transplanted plots was 45 per cent greater than from the directly seeded plots. This latter difference was a significant one with odds of greater than 19 to 1. It appears, therefore, that the method of starting lima beans indoors and carefully transplanting them to the field offers promise of giving an earlier crop with increased yields as has been suggested by Thompson (7). This method, of course, would be practical only with small plantings of lima beans.

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Natural Crossing of Lima Beans in Maryland During 1941

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IN ORDER to determine (a) the extent of natural crossing of lima beans in the field during 1941, (b) the variation between individuals of the same variety, (c) the difference between varieties, and (d) the effect of proximity of dominant or recessive types, the following experiment was conducted at the Bureau of Plant Industry Station, Beltsville, Maryland in 1941 and in 1942.

METHOD AND MATERIALS

The 1941 material was grown in rows 3 feet apart with the plants spaced 1 foot apart in the row. The plot contained 15 rows and was divided across the rows into blocks 10 plants long with a 2-foot aisle between plants of adjacent blocks. Thus B4, R11 in Table I refers to block 4 and row 11 in the plot.

When the majority of the pods had ripened, the plants were harvested in order, numbered, dried in the greenhouse and the seed saved separately. During the winter the seeds were examined by strong transmitted light and those with green cotyledons separated from those with white. In those cases where part of the cotyledon had faded but still retained green color in part of the seed, the seed was so recorded and kept separate in planting.

The four rows of green-cotyledon Henderson (listed in Table I) were from seed grown in a screened greenhouse in 1940. The cotyledons of the seed used for the greenhouse planting were green, and the resulting crop of seed was green-cotyledoned. The plants that produced Baby Fordhook, Fordhook and Concentrated Fordhook were true to type in 1941 in the field. Seed from these plants were planted in the field in 1942 and the per cent of recognizable hybrids obtained from this seed is presented in Table II.

Green-Seeded Henderson (Thorogreen) in rows B4–R11, B4–R13, and B4–R15 were adjoined on each end by families with larger plants and foliage and with pods that were wider, thicker, and slightly longer, containing white-cotyledon seeds. B4–R11 was adjacent on one side to the same general type containing white-cotyledon seeds, and on the other side to a sister green-cotyledon type. B4–R13 was flanked on both sides by the green-cotyledon type, whereas B4–R15 was the outside row in the block and had the green-cotyledon type on only one side. B27–R3, a Green Seeded Henderson, was surrounded on all sides by families producing plants that were larger or of different habit, with white-cotyledon seed and with longer pods that were thicker or wider or both.

There was a total of 800 white-cotyledon plants in the six blocks beyond the two ends of block 4, and 90 such plants in the block itself. The six blocks were divided equally at the ends of block 4; three were at the north end and three were at the south end. In this area there were only 81 green-cotyledon plants. This would give a ratio of 10 white-cotyledon plants to 1 green-cotyledon. Green-Seeded Henderson in row 3 of block 27 was surrounded on all sides by white-cotyledon families. For the entire field 50 feet wide and 407 feet long there were approximately 4,824 white-cotyledon plants and 90 green-cotyledon ones. This gives a ratio of 53.6 white-cotyledon plants to 1 green-cotyledon plant for the entire field.

B27–R15, a white-seeded line, was an outside row but was adjoined on each end and on one side by white-seeded lines of larger plant growth with larger leaves and with pods that were much longer and wider. B8–R12, Baby Fordhook, was surrounded on all sides by lines of a type that had a different plant habit, larger leaves, and pods that were longer, wider, and thicker, but with the same cotyledon color.

B26–R15, Baby Fordhook, an outside row, was surrounded on three sides by plants that were slightly smaller and earlier-maturing, with shorter, narrower, and flatter pods. B22–R10, another white-cotyledon type, was surrounded by related lines of a type whose plants and pods were similar to those of Concentrated Fordhook. B28–R11, Concentrated Fordhook, however, was surrounded by smaller, earlier-maturing plants with slightly shorter and narrower pods. B31–R11, Concentrated Fordhook, was adjacent on one side to a type with smaller plant, having narrower, thicker pods, and on the other side to large plants with longer, flatter pods. It was adjoined on both ends by plants of different habit with straighter, flatter pods.

The 1942 planting to test the hybridity of seed saved from individual plants of the 1941 test was made in rows 3 feet apart, with 6 to 12 inches between plants. Plants which clearly indicated by one or more characters that they were hybrids were pulled and stacked along the rows with roots up. Subsequent examinations of unpulled plants were made over a 2-week period and those about which there was any doubt were recorded as non-hybrids. A medium number of plants were doubtful, especially in some of the green-cotyledon material where all the pods were dry and faded before the examinations were started.

RESULTS

Table I shows a high percentage of seeds with white cotyledons from plants produced from green-cotyledon seed. These white-cotyledon seeds were presumed to be hybrids since previous genetic work (1) showed that there is a single factor difference between green cotyledon and white cotyledon with white cotyledon dominant. Since the seed embryo is a miniature resting plant it is possible to pick up the dominant white factor in the progeny of green-cotyledon plants as soon as the seed is ripe. The column showing the percentage of hybrids based on plant and pod characters in plants grown from these white-cotyledon seeds indicates that in certain progeny the presumption was proven correct. The late examination and consequent lack of immature or ripening pods on which to base a judgment resulted in some doubtful plants which appear in the table as non-hybrids. It is also possible that in certain families some of the seeds grown in 1941 may have

TABLE I—Percentage of White-Cotyledon Seed from Green-Cotyledon Plants, Percentage of Recognizable Hybrids from White-Cotyledon Seed Found on Green-Cotyledon Plants, and Percentage of Recognizable Hybrids from All Seed from Green-Cotyledon Plants Grown at Beltsville, Maryland, 1941

Total Number Seed	Per Cent White-Cotyledon Seed	Plants From White-Cotyledon Seed		Total Plants Grown	
		Number	Per Cent Hybrids	Number	Per Cent Hybrids
B4-R11 Green-Seeded Henderson					
39	74.3	22	90.9	28	71.4
142	70.4	74	94.6	98	71.4
91	54.9	26	69.2	42	42.9
77	66.2	35	68.6	51	47.0
115	50.4	40	62.5	73	34.2
105	46.7	37	78.4	82	35.4
91	38.5	31	77.4	72	33.3
93	62.4	46	80.4	85	43.6
53	56.6	24	100.0	41	58.6
57	63.2	33	94.0	50	62.0
B4-R13 Green-Seeded Henderson					
181	56.9	87	86.2	130	57.7
28	25.0	5	100.0	11	45.4
128	38.8	44	100.0	95	46.3
111	40.5	33	91.0	83	36.2
89	48.3	30	86 8	62	41.9
108	45.4	39	97.5	71	53.5
146	53.4	58	93.1	117	46.2
119	42.8	45	71.1	85	37.7
123	64.2	80	70.0	113	49.5
124	43.5	49	71.4	99	36.4
B4-R15 Green-Seeded Henderson					
99	58.6	53	62.3	88	37.5
65	63.1	36	75.0	58	46.5
89	56.2	40	70.0	73	38.4
90	65.6	40	62.5	58	38.5
104	69.2	57	57.9	74	44.6
84	83.4	47	55.4	54	48.2
85	84.7	59	27.1	72	22.2
105	78.1	68	53.0	88	40.9
81	75.3	43	41.9	59	30.5
B27-R3 Green-Seeded Henderson					
158	43.7	50	22.0	100	12.0
136	47.3	49	57.1	94	30.8
143	53.1	63	61.9	122	31.9
138	37.7	47	89.4	104	40.4
135	26.1	33	90.9	102	30.0
106	34.9	34	91.2	112	27.7
92	31.5	24	95.8	73	31.5
117	17.9	18	100.0	100	18.0
117	31.6	17	100.0	85	20.0
32	37.5	8	100.0	8	100.0

been faded sufficiently to be classified white and yet be genetically green.

In the 67 plants matured from seed that were faded (part white and part green) none was a recognizable hybrid, and in the 1320 plants from seed classified as having green cotyledons only 4 were definitely hybrids, which is a small number considering the possible errors of classification and of field work.

The percentage of hybrids found in the Green-Cotyledon Henderson plants was very high, even in row 13 of block 4, which was flanked on each side by green-cotyledon plants. It is surprising that more hybrids were not found in B27–R3, which row was completely sur-

TABLE II—PER CENT OF RECOGNIZABLE HYBRIDS IN FAMILIES FROM BABY FORDHOOK, FORDHOOK, AND CONCENTRATED FORDHOOK BUSH LIMA BEAN PLANTS GROWN AT BELTSVILLE, MARYLAND, 1941

Number of Plants Grown	Per Cent Hybrids	Number of Plants Grown	Per Cent Hybrids
B27–R15 Baby Fordhook		*B22–R10 Concentrated Fordhook*	
125	6.4	18	5.5
55	5.5	33	9.1
57	5.3	28	7.1
68	10.3	56	0.0
61	6.6	48	6.2
49	2.0	6	33.3
35	8.6	39	5.1
54	9.3	31	9.7
54	5.6	18	0.0
55	3.6		
B8-R12 Baby Fordhook		*B28-R11 Concentrated Fordhook*	
100	5.0	17	17.6
94	5.3	24	20.8
71	4.2	23	26.1
96	6.2	28	14.3
128	0.8	22	18 2
72	4.2	21	9.5
71	2.8	27	25.9
49	6.1	22	18.2
91	1.1	29	10.3
137	8.0	40	20.0
B26–R15 Fordhook		*B31-R11 Concentrated Fordhook*	
37	5.4	40	27.5
25	8.0	37	10.8
28	10.7	32	25.0
8	0.0	28	14.3
19	0.0	37	13.5
25	8.0	22	9.1
27	3.7	40	25.0
		29	6.9
		31	32.2
		48	18.7

rounded by dominant types, than in B4–R13 where the different type pollen had to be transferred at least 9 feet from the nearest parallel or side row. From the three tests in block 4 there is no clear evidence that a shorter distance of transfer made any difference in the amount of hybridization effected. The preponderance of white-cotyledon plants over green-cotyledon plants in the field, with a ratio of 53.6 to 1, means a great deal more white than green-cotyledon pollen. It may be possible that even if the green-cotyledon plant is selfed before white-cotyledon pollen is deposited on the stigma by the insects, the white-cotyledon pollen tube would grow down the stigma faster than the green-cotyledon pollen and thus affect fertilization. Individual bees and other insects (2) have been observed working over distances of more than 100 feet in lima bean plantings before leaving the field.

In the case of the Baby Fordhook variety (3) it was very easy to detect hybrids, all of which made larger plants, leaves, and pods. By comparing the data in Table I with that in Table II it is evident that Baby Fordhook, Fordhook, and Concentrated Fordhook did not show as much natural crossing in the field as the Green-Seeded Henderson type, probably due, at least in part, to less green-cotyledon pollen due to fewer plants of this type and greater difficulty in detecting crosses. There were marked differences in the amount of field hybridization in plants of the same variety with the same exposure to plants with dominant characters. The lower percentage of recognizable hybrids in B22–R10 families may have been due to the inability to detect the hybrids from crosses between similar types.

Of the 95 progenies grown in 1942 to determine hybridity, as presented in Tables I and II, only 4 showed no hybrids and these were from white-cotyledon parents.

Summary

The percentage of recognizable hybrids in families from three types of bush lima beans grown in the field at Beltsville, Maryland, in 1941 varied from 0 to 100, in many of the progenies exceeding 25 per cent.

The Green-Seeded Henderson type, (Thorogreen, Clarks Bush, Cangreen) showed more field hybridization than Baby Fordhook, Fordhook, and Concentrated Fordhook, probably due, at least in part, to greater abundance of white-cotyledon pollen in the experimental field and to greater ease in detecting hybrids in a recessive green-cotyledon type.

In a mixed planting of green- and white-cotyledon types, selection of white-cotyledon seed from green-cotyledon plants will obtain most of the field hybrids.

There is considerable variation in the amount of field hybridization in individual plants of the same variety with equal exposure to foreign pollen.

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The Breeding and Improvement of Edible Cowpeas

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ALTHOUGH the cowpea (*Vigna sinensis*, Hassk) has been grown in America for a long time, relatively little attention has been given the crop as a source of high protein food.

Most of the vast acreage in the sandy land areas in the South that is planted to cowpeas and related crops is heavily infested with the rootknot nematode (*Heterodera marioni*, Goodey) and wilt producing organisms of various kinds (*Fusarium sp.*). Control or eradication of these pests by means of resistant or immune host crops is almost impossible, because of the few crop possessing immunity and the large number of susceptible host plants that include both cultivated plants and weeds. The most important improvement needed in edible cowpeas is the development of highly palatable, wilt and nematode resistant strains with varying fruiting habits to fit the needs of home and market gardens and commercial canneries. Wilt and nematodes are factors limiting production of the better horticultural varieties of cowpeas in the sandy soils throughout the entire South as well as other areas. In Louisiana, these pests are so severe that other areas are depended on to grow our edible cowpea seed.

For the above reason, a breeding and improvement program was started in 1940 to produce edible strains that mature early enough so that these diseases are not a factor in production, and others that are extremely resistant or immune to the diseases.

The methods used are as follows:

1. Selections are made within varietal seed stocks that had been grown continuously on diseased soil for the past five years.
2. Seed are collected from the best stocks over the area.
3. A breeding program is being conducted.

Plant selections were made in the fall of 1940 for Crowder and Cream types that showed resistance to wilt and nematodes from varieties known to be susceptible to the troubles. Seed from these plant selections were grown in 1941 and 1942 on heavily infested soils.

Some of the selections segregated in color and other characters indicating that there were some natural hybridizing in the field and in this way picked up resistance, while others have been homozygous for a number of characters corresponding to their particular varietal type, but indicate definitely more resistance than other seedlings within the same variety. This resistance had a tendency to increase in each successive generation.

Sample collections of seed were made from various parts of the South and were grown on heavily diseased soil with varying results. From this collection of seed a strain of early purple hull pea was found that matures a crop of seed earlier than any other strain of cowpeas the writer has ever grown. This strain is definitely a bush or bunch type that produces a heavy yield of highly palatable, purple hulled, white redish eyed peas. An early spring planting of this strain will produce good seed yields before weather conditions are favorable for disease attacks.

The two above mentioned methods of approach are the fastest methods under certain conditions, but they are by no means the best. Breeding for resistant varieties of edible cowpeas offers the best practical approach to the problem. Resistance in all cases is determined by growing various varieties and seedlings on heavy wilt and nematode infested soils under constant check. Susceptible varieties being used as checks and to feed and increase the population of the organisms. Crosses were made between known resistant strains of clay and iron on susceptible Crowder and Lady varieties. The F_1 plants of an Iron Clay x Lady Cross were of an intermediate, semi-running type. These plants were resistant both to cowpea wilt and nematodes. These F_1 plants produce an unusually heavy crop of highly palatable, large, semi-Crowder type peas. The seed pod yields of the hybrid were so outstanding that plant counts were made on both parents and the hybrid, and the F_1 plants outyielded either parent by more than three to one in number of seed pods per plant.

The F_2 plants from the above cross segregated into 3 to 1 ratio of resistance to susceptible plants as has been found by other workers on the subject. These plants were grown on heavily infested soil and received an additional inoculation of incubated diseased plant tissue to be sure of infection. From the total population of several hundred F_2 individuals of this cross, resistant plants were selected that gave high yields of good quality edible seed plus other factors of agronomic value.

Other crosses were made in 1940 between resistant stocks and several other varieties of edible types to find which parents to use to get the desired characters of horticultural and agrononmic value. From these crosses several wilt and nematode resistant Crowder strains were selected for their adaptability to the area, and their ability to produce high yields of edible semi-bladder podded peas. The strains vary in color from white to cream to brown and in number of peas per pod from 15 to 20 or 21. This compares in number of peas per pod with the standard Crowder varieties that vary from 10 to 14 in most cases.

Wilt and nematode resistant varieties and strains from other areas were grown along with the above work. These strains showed definite resistance to nematodes, but failed to make a crop due to a severe attack by wilting organisms and a possible change of growing conditions under which they originated. This wilted condition of the out-of-state strains were so severe that they could not be classed as wilt resistant stocks under our conditions.

CONCLUSIONS

From this it is concluded that under conditions of early spring planting cowpea wilt and nematodes do not materially affect the yields of some early maturing varieties due to their ability to mature before weather conditions are favorable for diseases to develop. Through a breeding program edible cowpeas can be improved in palatability, yields, adaptability, and wilt and nematode resistance. This work must be carried on in the same general area where the crop is to be grown. The results obtained from the use of resistant materials from other areas indicate that in the South there are different strains of the organisms that cause cowpea wilt.

Interrelation of Varieties and Spacing on Early and Total Yield of Market Peas[1]

By Russell E. Larson, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE effect of various spacings on yields of market peas is of particular interest under present conditions. The probable seed shortage has made it highly desirable to obtain as large yields as possible from a given quantity of seed. Hulbert and Burkart (1) reporting on the rate of seeding of seed peas, state that an average of four to five plants per square foot produced maximum yields, regardless of variety. They further conclude that varying rates of seeding dependent upon size of seed are necessary for maximum yields of various varieties.

This study was made to determine the interaction between variety and spacing on yields of market peas. The varieties grown were Nott's Excelsior, Little Marvel, Laxton's Progress, Blue Bantam, Thomas Laxton, and Improved Gradus. All were dwarf types except Thomas Laxton and Improved Gradus which develop to a height of 30 to 36 inches and are considered medium-tall varieties.

A split plot design was used in which the five spacing treatments were laid out in rows crosswise of each block. Randomization of the spacing treatments in different blocks was used, however. The six varieties were planted at random within each of the spacing plots. Four replicates were grown and data on early and total yields were obtained. The five spacing treatments consisted of ½, 1, 2, 4, and 8 inches between seeds in rows 3 feet apart. The required number of seeds for each spacing was obtained by count. An additional 10 per cent was added to allow for faulty germination. The seed was not treated with a seed protectant, however, it appeared that only a small percentage failed to emerge and a germination of greater than 90 per cent was obtained. The seeds were planted on April 6, the first harvest made on June 16, and the last on June 30, 1942.

Early yields based on results of the first and second harvests, are presented in Table I. The analysis of variance for early yields gave highly significant F values for varieties, spacings, and for the interaction varieties by spacings. The plants spaced at 1 inch were most productive of early yields, although insignificantly greater than the ½ inch spacing. The difference between means of the 1-inch and 2-inch spacings is highly significant. However, it is interesting to note that the greatest differences exist between means of the medium-tall varieties, and only relatively minor differences for the dwarf varieties, as is shown in Table II. Thus, it appears that with the dwarf varieties, a distance of 2 inches between plants does not seriously affect the maturity of the crop and hence the early yield; whereas the medium-tall varieties should be seeded at a spacing of 1 inch in order to realize a greater early yield.

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[1] Contribution No. 624 of the Rhode Island Agricultural Experiment Station.

TABLE I—EARLY YIELDS* IN BUSHELS PER ACRE OF FIVE VARIETIES OF PEAS AT FIVE DIFFERENT SPACINGS

Varieties	Spacings (Inches)					
	½	1	2	4	8	Mean†
Nott's Excelsior	55.3	62.9	61.2	49.1	19.0	49.5
Little Marvel	102.7	99.2	79.5	31.1	17.3	66.0
Laxton's Progress	75.0	75.0	71.6	46.7	19.0	57.5
Improved Gradus	90.6	87.1	45.6	24.2	12.1	51.9
Thomas Laxton	144.2	175.3	112.4	50.8	26.6	101.9
Mean‡	93.6	99.9	74.1	40.4	18.8	

*First and second harvests.
†Significant difference = 13.0 bushels; highly significant difference = 18.3 bushels.
‡Significant difference = 9.6 bushels; highly significant difference = 13.5 bushels.
Interaction varieties by spacings; significant difference = 30.0 bushels; highly significant difference = 41.4 bushels.

The early harvest of the variety Thomas Laxton exceeded that of Little Marvel, its closest rival, by 35.9 bushels per acre, a highly significant difference. Little Marvel exceeded the average early yields of Improved Gradus and Nott's Excelsior by 14.1 and 16.5 bushels per acre respectively. Both differences exceed the 5 per cent level of significance. No early harvest was made of the Blue Bantam variety as it was insufficiently matured.

TABLE II—EARLY YIELD* OF PEAS IN BUSHELS PER ACRE—THREE DWARF VARIETIES AND TWO MEDIUM-TALL VARIETIES AT FIVE DIFFERENT SPACINGS

Stature	Number of Varieties	Spacings (Inches)				
		½	1	2	4	8
Medium tall	2	117.4	131.2	79.0	37.5	19.3
Dwarf	3	77.7	79.0	70.8	42.3	18.4

*First and second harvests.

That spacing of peas too close together may be as detrimental to early yield as spacing too far apart, is shown in Table I. The early yield of Thomas Laxton at 1 inch between plants produced a significantly higher yield of 31.1 bushels per acre over the ½ inch spacing, and 62.9 bushels per acre over the 2-inch spacing. The early yield of Improved Gradus at a spacing of 2 inches was approximately one-half of the yield obtained when the seeds were planted at 1 inch apart. No significant differences are found within each of the dwarf varieties for the three closest spacings.

The analysis of variance for total yield gave highly significant F values for spacings and varieties, but the interaction of varieties by spacings was not significant. Total yields in bushels per acre are presented in Table III.

The total yields of all varieties were uniformly increased as the average distance decreased from 8 inches to 1 inch. Seeding as close as ½ inch did not increase the total yield over that of the one inch spacing. As an average of all varieties, the difference between means of the 1-inch and 2-inch spacings is 23.3 bushels and is highly significant.

TABLE III—TOTAL YIELD IN BUSHELS PER ACRE OF SIX VARIETIES OF PEAS AT FIVE DIFFERENT SPACINGS

Variety	Spacings (Inches)					
	½	1	2	4	8	Mean*
Nott's Excelsior	158.2	154.7	135.7	118.4	75.2	128.4
Little Marvel	182.4	166.8	158.2	89.0	51.9	129.7
Blue Bantam	118.4	132.3	132.3	72.6	29.4	97.0
Laxton's Progress	175.5	178.1	154 7	115.8	67.4	138.3
Improved Gradus	153.0	152.1	108.9	64.8	34.6	102.7
Thomas Laxton	214.4	218.7	172.9	111.5	72.6	158.0
Mean†	167.0	167.1	143.8	95.3	55.2	

*Significant difference = 16.9 bushels; highly significant difference = 23.4 bushels.
†Significant difference = 12.9 bushels, highly significant difference = 18.0 bushels.

The difference between means of the 1-inch and 2-inch spacings for the dwarf and medium-tall varieties, as shown in early yields, is further amplified in total yields. A difference of 44.5 bushels per acre between means of the 1-inch and 2-inch spacings for the medium-tall varieties is shown in Table IV. This represents a 31 per cent increase in total yield of the 1-inch over the 2-inch spacing. The dwarf varieties differ for the same spacing treatments by 12.8 bushels per acre or an increase of only 9 per cent. Although the difference in yielding ability of the two medium-tall varieties is considerable, they both exhibited a great reduction in yield when the spacing was increased from 1 inch to 2 inches between plants.

TABLE IV—AVERAGE TOTAL YIELD IN BUSHELS PER ACRE OF FOUR DWARF AND TWO MEDIUM-TALL VARIETIES OF PEAS AT FIVE DIFFERENT SPACINGS

Stature	Number of Varieties	Spacings (Inches)				
		½	1	2	4	8
Medium tall	2	183 7	185.4	140.9	88.1	53.6
Dwarf	4	158.6	158.0	145.2	98.9	56.0

In this test Thomas Laxton was superior in total yield to all other varieties. The differences in total yield among the varieties Nott's Excelsior, Little Marvel, and Laxton's Progress were not statistically significant. Blue Bantam and Improved Gradus appeared to be poorly adapted to local growing conditions.

Since seed size of different varieties of peas varies considerably, it is important that planting recommendations be made for each specific variety. For example, the variety Blue Bantam contains approximately 88,000 seeds per 60 pound bushel, whereas the small-seeded variety Nott's Excelsior contains about 140,000 seeds per 60 pound bushel. Expressed differently, it took 2.2 bushels of peas per acre to seed the Blue Bantam variety at 1 inch between plants and three feet between rows, whereas, it took only 1.4 bushels of peas of the Nott's Excelsior variety to seed a similar area using the same planting distances. Table V indicates the approximate amount of seed used for each variety at the different spacings.

TABLE V—BUSHELS OF SEED OF SIX VARIETIES OF PEAS NEEDED TO PLANT AN ACRE AT EACH OF FIVE DIFFERENT SPACINGS (THREE FEET BETWEEN ROWS)

Variety	Spacings (Inches)				
	½	1	2	4	8
Nott's Excelsior	2.72	1.36	0.68	0.34	0.17
Little Marvel	3.32	1.66	0.83	0.42	0.21
Blue Bantam	4.35	2.18	1.09	0.55	0.28
Laxton's Progress	4.27	2.14	1.07	0.54	0.27
Improved Gradus	4.05	2.02	1.01	0.51	0.26
Thomas Laxton	3.62	1.81	0.91	0.45	0.23

SUMMARY

Although slightly greater yields were obtained when seeds were planted at 1-inch intervals, the data indicate that dwarf varieties of peas may be spaced at a distance of 2 inches without causing a significant reduction in early and total yields. The data further suggest that seed of the medium-tall varieties should be spaced 1 inch apart to obtain a maximum early and total yield. Decreasing the spacing to ½ inch or doubling the quantity of seed appears to have no practical value, and may, in certain cases, be detrimental.

It appears that seeding rates must be specific for each variety due to the vast difference in number of seeds per bushel.

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Species Crosses in the Genus Phaseolus

By A. B. STRAND, *University of Tennessee, Agricultural Experiment Station, Knoxville, Tenn.*

THE purpose of this article is to report the results of trials already carried out in the production of hybrid beans with the object of encouraging others to make crosses combining the good qualities of species. The Mexican bean beetle every year causes serious losses to the bean crop in the South. The extent of the losses varies from year to year, according to weather conditions and the number of overwintering adults. Early, or April, plantings of common garden beans often are grown without protection from sprays. In later plantings some of the common garden varieties are more seriously damaged than others. Table I is a summary of the results of trials with common bush beans during the summer of 1938.

TABLE I—COMPARATIVE YIELDS PER ACRE OF FOUR NATIVE BEAN VARIETIES, SPRAYED AND UNSPRAYED (AVERAGE OF TWO PLANTINGS, JUNE 15 AND 22, 1938)

Variety	Sprayed			Unsprayed		
	U. S. No. 1 (Bushels)*	U. S. No. 2 (Bushels)	Culls (Bushels)	U. S. No. 1 (Bushels)	U. S. No. 2 (Bushels)	Culls (Bushels)
Giant Stringless Green Pod	243.01	48.94	——	74.16	62.64	4.00
Asgrow Stringless Green Pod	209.53	37.03	——	63.60	43.83	1.40
Tennessee Green Pod	137.21	5.04	——	54.56	24.96	2.24
Red Refugee	59.20	57.83	——	7.20	8.80	4.40

*One bushel of green beans is 30 pounds.

Similar but more pronounced results were obtained with oriental species, unsprayed. The Urd is highly resistant to the bean beetle, whereas Adsuki is almost as susceptible as the common garden bean. The Mung and Rice beans are intermediate in susceptibility. Other species of *Phaseolus* tested have shown some degree of tolerance to the Mexican bean beetle. Table II is a summary of results with oriental species tested during the summer of 1938.

TABLE II—COMPARATIVE YIELDS PER ACRE OF FOUR ORIENTAL BEAN SPECIES, UNSPRAYED, AND BEAN-BEETLE DAMAGE TO LEAVES (AVERAGE OF TWO PLANTINGS, JUNE 15 AND 22, 1938)

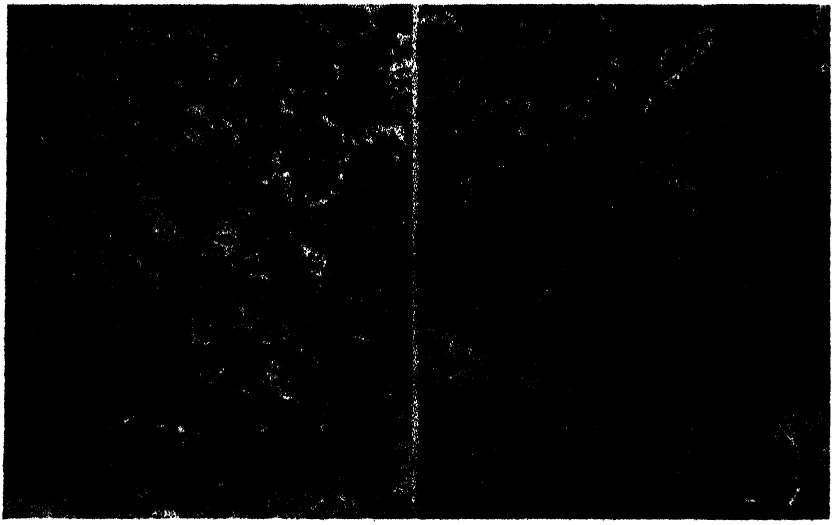
Variety	Number of Days to Harvest	Shelled Dry Weight (Pounds)	Leaf Damage
Rice	99	1579.20	Slight
Adsuki	99	1139.40	Severe
Urd	116	1681.40	Practically nil
Mung	71	995.40	Slight

PLANT MATERIAL AVAILABLE

Seed of the oriental species were obtained from W. J. Morse, Senior Agronomist of the United States Department of Agriculture. Their adaptation is similar to that of the cowpea, all requiring warm summer weather for satisfactory development. The Mung, Urd, and Rice beans are to be compared to the cowpea, while the Adsuki is more like the common bean. The plants are annuals, half twining in habit, with the exception of Urd, which rarely is twining. They make vigorous growth whether the season is wet or dry. The pods are very small and do not possess edible qualities. In Tennessee, during warm, moist weather they are subject to mild attacks of mildew and leaf spot. Wilt and root-knot nematode have been present, but have not caused any serious loss of plants.

Once the plants become established they are very tolerant to insect pests. Mexican bean beetle and bean leaf beetle do very little damage to the Urd, Mung, and Rice. Leafhoppers attack them, but do not cause appreciable injury. These varieties are subject to injury from seed corn or bean maggot, especially if planted too early in the spring or in soil containing large quantities of partly decayed organic matter. They are more subject to injury from bean weevils than are soybeans, but less so than cowpeas or common beans. Crosses of Urd with the common garden bean have produced offspring sufficiently tolerant to the attacks of Mexican bean beetle to make dry shell beans without the use of spray for beetle control, even in seasons of severe infestation.

Urd is the most resistant to the Mexican bean beetle. Fig. 1 shows plants of Urd and soybeans in the same field. The soybeans were practically defoliated, while the Urd plants suffered very little damage. Urd is adapted to a fairly wide range of soil conditions. It does best,



Urd Soybeans

FIG. 1. Mexican bean beetle damage. Note that the soybeans were practically defoliated, whereas Urd was little damaged.

however, on a fertile sandy loam soil having good drainage. It is a low-spreading annual, rarely attaining a height greater than 3½ feet. It is similar to the Mung, but can easily be distinguished from the latter by the much shorter, stouter, hairy pods. The average length of pods is 2⅛ inches. The seeds are blackish to olive, oblong to round, averaging ⅛ inch in diameter. As human food, the seeds are the only part that can be used, and they seem to be far less desirable than any of the other species.

Urd is the most resistant of the species to all insects and diseases that have been present in the Experiment Station plots. A mild attack of mildew and leaf spot occurred once during a period of moist, hot weather, but disappeared as soon as favorable growing conditions returned. Dr. C. F. Andrus (1), Plant Pathologist of the Division of Fruit and Vegetable Crops and Diseases, United States Department of Agriculture, states: "Our observation on the Urd bean are confined to the single strain which you gave us in October, 1941. We find it to be highly resistant to bacterial blight (*Bacterium phaseoli*) and probably resistant to rust (*Uromyces phaseoli typica*), at least to that form prevailing here this fall. It is quite susceptible to common bean mosaic, powdery mildew, and root knot. In respect to root knot, our experiments do not prove that it might not have a degree of hardiness which would enable it to survive attack by the root-knot nematode, but we do know that well-developed knots are formed. The bacterial blight and root knot observations are from greenhouse inoculations. Rust, mosaic, or powdery mildew data are based on field observations."

Developing a Technic Suited to the Particular Problem

All species of *Phaseolus* are considered difficult to cross. This is true especially of oriental species, because of their very small floral parts. All attempts to use these species for female parents failed. Then too the oriental species, as Table II shows, are later in maturing. This fact made it necessary to delay the planting of the common garden varieties so as to have them come into bloom at the same time as the oriental species. Field methods of crossing failed. The method used consisted in growing the female parent (usually *Phaseolus vulgaris* type) in 5- and 6-inch clay pots. The pots were embedded in soil and watered carefully to avoid any shock to the plant at the time of fruit set. When a few flowers were receptive, three or four of the plumpest buds were used for crossing. All of the other buds were removed. After the pollen was deposited on the stigma the whole plant was covered with a glassine bag to provide high humidity for pollen growth and fertilization (Fig. 2). There is only a short season in the fall when the work can be done successfully, and for that reason few species crosses have been made. A large number of back crosses were made in the greenhouse last winter. Many of these set pods, but when they were about half grown the pods dropped off. Attempts were made to prevent this fruit drop by spraying with plant hormones, but with no success. Variety crosses that were made at the same time as the back crosses produced viable seed. This is additional proof that conditions were not satisfactory for species crossing.

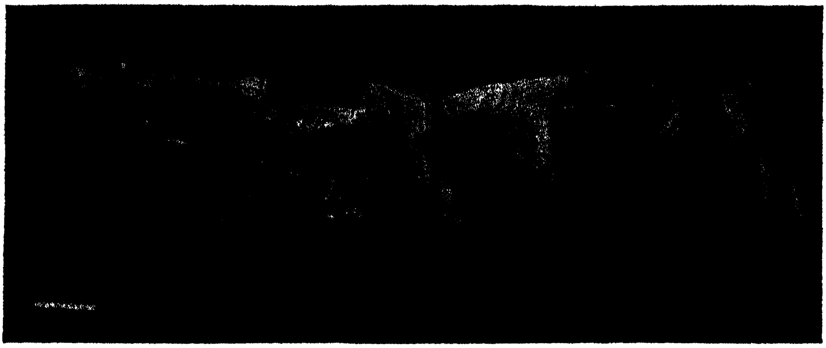


FIG. 2, Glassine bags provide high humidity for pollen growth and fertilization.

A STUDY OF INHERITANCE AND UTILIZATION OF OFFSPRING

The main objective in this breeding program is to secure offspring that are resistant to Mexican bean beetle. Crosses of Urd (*Phaseolus mungo*) and *P. vulgaris* have been made and subjected to severe attacks of the beetle. In all cases so far, resistance appears to be a recessive characteristic. One selection from a back cross produced an abundance of seed this past summer from plants that were not given protection from the Mexican bean beetle. These plants were grown alongside of the soybean shown in Fig. 1.

A genetic study was made of seed-coat color of the species cross Asgrow Stringless Green Pod (*Phaseolus vulgaris*) and Urd (*P. mungo*) Asgrow Stringless Green Pod was the female parent. The seed-coat color was Agate-Grey (43 A-1) (2), splashed and mottled over the entire surface with Graphite (48 C-7). Urd was the male parent. Its seed-coat color was Gunmetal (48 C-2), splashed and mottled over the entire surface with Olive Brown (15 H-7). The following is a seed-coat-color study of the first three generations.

Generation F_1

Mottled	Number of Seed
Gunmetal (48 C-2) Olive Brown (15 H-7)	1

Generation F_2

Mottled	Number of Seeds
Antique Bronze (14 L-10) Clove (15 C-12)	3

Generation F_3

Mottled	Number of Seeds	Self	Number of Seeds
Gunmetal (48 C-2) Clove (15 C-12)	15	Clove (15 C-12)	11
Gunmetal (48 C-2) Olive Brown (15 H-7)	14	Ivy Green (16 L-9)	4
Ivy Green (16 L-9) Antique Bronze (14 L-10)	7		
Beeswax (14 L-9) Bronze Green (16 L-9)	5		
Agate Grey 43 (A-1) Graphite (48 C-7)	3		
Total	44		15

Other preliminary genetic studies have been started. The primary object of this project, however, is to combine the good qualities of certain species of *Phaseolus* in such a way as to produce a new individual that will supply desired qualities to the offspring from both parental lines. Where both parents used in a cross have distinct characteristics, such as the Mexican bean beetle resistance of Urd (*Phaseolus mungo*) and the excellent edible qualities of Asgrow Stringless Green Pod (*P. vulgaris*), some future individual should possess both qualities. No selections up to the present time possess these characteristics in proper combination, but certain lines possess more resistance than others. These have been retained for further back crossing and line selections.

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2. MAERZ, A., and PAUL, M. REA. A dictionary of color. McGraw-Hill. 1930. References are to plate, column, and row; *e.g.*, 43 a-1 refers to plate 43 column a, row 1.

A New Variety of Muskmelon for Puerto Rico

By Arturo Riollano, *Agricultural Experiment Station,*
Rio Piedras, P. R.

NUMEROUS varieties of cantaloupe and muskmelon have been tried without success in Puerto Rico. Most of the varieties tried have been severely attacked by downy mildew, a disease caused by *Peronoplasmopora cubensis,* E. F. Clinton, which also attacks most of the cucurbits grown in the tropics. Crop failures in the different attempts to introduce new melon varieties have been mainly due to this fungous disease. In one of these trials the following varieties were tested: Hale's Best, Hale's Best No. 45, Honey Rock, Honey Moon, Honey Dew, Honey Dew Pink Flesh, Honey Dew Gold Rind, Tip Top, Fordhook, Imperial Special, Netted Gem, Melon Peach, New Delicious, Spiny, Jenny Lind, Hearts of Gold, Pollock 10–25, Pearly Pink, Texas Cannon Ball, Cuban Castillian, Rocky Dew Orange, and Rocky Dew Green.

The last three named varieties, Cuban Castillian, Rocky Dew Orange and Rocky Dew Green, produced a satisfactory crop, thus showing remarkable resistance to downy mildew. However, the quality in general of these three varieties was below that of the common commercial varieties.

Another trial was started including these mildew resistant varieties and such other varieties as: Cooper's Sweetheart, Hale's Best No. 36, Banana and Smith's Perfect. Seed from all of the varieties for this trial was obtained through the courtesy of Dr. H. W. Schneck, from the Kilgore Seed Company of Plant City, Florida. The results obtained confirmed the mildew resistant characteristics of Cuban Castillian and the Rocky Dew varieties. Cooper's Sweetheart, Hale's Best No. 36, and Banana were a complete failure. However, Smith's Perfect was surprisingly very resistant to downy mildew, and furthermore, capable of producing a satisfactory crop of high quality fruit.

This led to establishing a more detailed trial in which Rocky Dew Orange, so far the most promising variety from the mildew resistant group, was compared again with the new Smith's Perfect. When the weight of fruit was considered, the results showed that Smith's Perfect outyielded the other variety in a significant way by 33 per cent. Though Smith's Perfect produced smaller fruit, its quality, uniformity in external and internal characteristics, and high yield made this variety far superior to Rocky Dew Orange.

Smith's Perfect is a new variety of melon developed at Florida from an introduction made from the West Indies. It is very resistant to downy mildew, a vigorous grower producing round fruit averaging about 3 pounds, uniformly netted, with thick rind of green color which turns greenish yellow upon ripening. The fruit is able to withstand readily the rainy season without cracking. The flesh is of medium thickness, of deep orange color and of agreeable flavor. It may be concluded that at last a new promising variety of melon has been found which is adapted to this island and suitable for long distance shipping as well as for local marketing.

Varietal Characters of Importance in Paprika Breeding[1]

By W. C. BARNES, *S. C. Truck Experiment Station, Charleston, S. C.*

IN 1939 the United States imported six million pounds of paprika. Most of this supply has been cut off by the war. Our need for this product is being partially met through production by some natives of Yugoslavia who came to America with a supply of seed just prior to the invasion of their country. In 1942 paprika was grown in Louisiana and South Carolina by these Yugoslavs. Other small lots of seed have found their way to America from time to time and small centers of production now exist in Florida and California.

The term paprika (Yugoslav for pepper) is used in commerce to indicate a dry, finely ground, mild, sweet, highly colored pepper. Most of it was formerly imported from Hungary, Yugoslavia, Portugal and Spain. Apparently different varieties were grown in the various centers of production. Most of the varieties that have found their way to this country are extremely variable. Many contained high percentages of plants that produced pungent pods. Other characteristics that are variable are plant type, pod shape, color, and wall thickness.

A tabular description of the important characters of the varieties grown at the South Carolina Truck Experiment Station in 1942 is given in Table I. If paprika varieties have names in Europe they are not known in this country. In order to simplify this paper the varieties have been labeled according to the source of the seed grown at this Station. Carolina No. 1, Carolina No. 6, and Dennes Special are Hungarian types imported from that portion of Yugoslavia near Hungary, whereas Carolina No. 7 and a similar variety which was discarded in 1941 are from the portion of Yugoslavia near Greece. The variety from Georgia is apparently the same as a variety obtained from Portugal, while McInnis was imported from Spain. The European origin of California is not known.

Pods of a good variety should be mild, sweet, highly colored, easy to pick, and easy to dry. They should also have a small placenta that crushes readily so that it can be removed in processing. The exact combination of plant characters that will give best results has not been fully determined.

CHARACTERS OF IMPORTANCE IN A BREEDING PROGRAM

The Shape of the Pod Base:—This is correlated with the readiness with which the pod separates from the calyx. Pods with rounded bases attached to a cup-shaped calyx separate readily from the calyx and are easy to pick whereas pods with a saucer calyx, as a rule, do not readily separate from the calyx. If the pod wall is torn in picking the pod usually becomes black during the drying process and must be discarded. If the calyx sticks to the pod so firmly that the peduncle is broken, it must be laboriously removed to prevent its going into the

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[1] Technical contribution No. 101 from the South Carolina Experiment Station (Truck Experiment Station Branch).

TABLE I—A DESCRIPTION OF SOME PAPRIKA VARIETIES*

Calyx	Peduncle	Pod						Plant Habit
Shape	Shape and Length	Shape	Length† (Inches)	Base	Apex	Internal Color	Wall Thickness	
Carolina No. 1								
Cup to funnel	Re-curved, long	Slender	3.5	Rounded to slightly flattened	Pointed, elephant snout	Light red or bronze Few red	Thin	Upright
Carolina No. 6								
Mostly funnel	Re-curved, long	Slender	3.4	Slightly rounded	Pointed, elephant snout	Light red or bronze, few red	Thin	Mostly upright
Carolina No. 7								
Saucer	Erect, short	Conical	3.0	Mostly flat	Pointed	Mostly red; few bronze	Medium thin	Spreading
Dennes Special								
Cup to funnel	Re-curved, long	Slender	3.5	Slightly rounded	Pointed, elephant snout	Mostly light red or bronze	Thin	Upright
McInnis								
Saucer	Re-curved, long	Rectangular, large	5.0	Flat	Blunt	Medium red	Thick	Spreading
California								
Saucer	Re-curved, medium	Slender	3.1	Mostly flat	Slightly blunt	Red	Medium thick	Spreading
Georgia								
Saucer	Re-curved, short	Conical	2.6	Flat	Bluntly pointed	Mostly light red	Thick	Spreading
Spanish								
Saucer	Re-curved, medium	Blocky, squarish large	3.0	Very broad flat	Very blunt nosed	Mostly red	Thin	Spreading

*Carolina Nos. 1, 6, and 7, and Spanish from Carolina Paprika Mills. McInnis and California from California Experiment Station and Associated Seed Growers. Dennes Special from Louisiana Experiment Station. Georgia from Georgia Experiment Station.

†Figures show relative length of pods produced under similar conditions.

finished product. Naturally green woody stems do not improve the quality of the finished product. The problem of ease of picking therefore assumes major importance.

Bearing Habit:—Pods with recurved peduncles often touch the soil and rot during rainy periods. On the other hand, fully erect pods such as those borne by Carolina No. 7 often weight the plant down and cause the branches to touch the soil. Therefore, a partially erect peduncle bearing a long slender pod will probably be most desirable. However, in harvesting, erect pods are more readily located than pendant ones, a factor of much importance.

Pod Shape:—At the present time, it is believed a slender pod such as that of Carolina No. 1 (pods of several varieties are shown in Fig. 1) will prove to be the ideal shape. Such pods dry with greater ease and retain their original shape whereas most of the others shrivel and

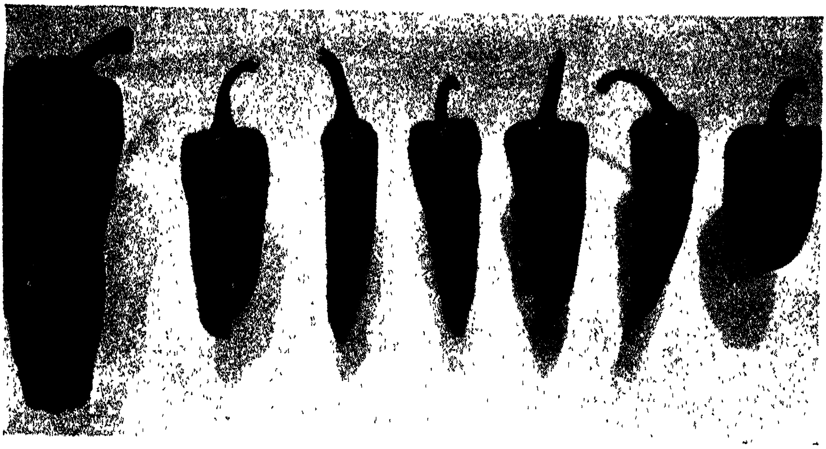

FIG. 1. Pods of some paprika varieties (left to right) McInnis, California, Carolina Nos. 1, 6, and 7, Dennes Special and Georgia.

frequently pack together in the drying bags. However, the slender pod varieties all have thinner pod walls than the others and it is possible that the latter characteristic, rather than shape is responsible for the ease in drying. In broad flat-based types such as Spanish, water collects around the calyx and rotting frequently occurs. In order to have a long slender pod, the apex must of necessity be sharply pointed. The "elephant snout" apex of Carolina No. 1 is typical of the Hungarian type of paprika varieties.

Pod Color:—All of the varieties grown developed excellent external pod color. However, the internal pod color varies greatly from plant to plant. At present California is the only variety which produces a high percentage of pods with good internal color. Selections for dark red internal pod color have been made in Carolina No. 7, and some of the single plant selections show uniformly good internal color after only one generation of selfing. Pods of McInnis begin ripening at the apex which usually becomes over ripe and rots before the base is properly colored.

Thickness of Walls:—A thin pod is one of the most important characters. Pods with thin walls dry more readily and yield a higher percentage of marketable product. When difficulties are encountered in drying, pod color is usually poor because of oxidation or attack of microorganisms.

After selfing for one generation it is evident that many lines are homozygous for most characters whereas others are somewhat heterozygous. In single plant selections of Carolina No. 7 pungency was eliminated in the first generation of selfing. By rogueing a commercial planting the percentage of plants producing pungent pods was reduced from approximately 5.0 per cent in 1941 to 0.75 per cent in 1942. No one line of No. 7, however, has all of the good characters available in this variety. Selection within Carolina No. 1 now shows promise of more nearly realizing the ideal than selection within any other variety.

This variety has apparently undergone some hybridization in the past and offers a wide variation of characters for study. Only the future can tell how difficult it will be to fix the desirable types that have been discovered.

Since no one variety possesses all the desirable characters, breeding work has been initiated to combine certain of the desirable features of the various varieties.

Observations on Culture and Handling of the Dish Rag Gourd in Maryland

By R. E. WESTER and V. R. BOSWELL, *Bureau of Plant Industry Station, Beltsville, Md.*

THE dish rag gourd plant has not been grown commercially in the United States to any important extent. Before the present war, the bulk of the vegetable sponges used in this country were imported from Japan, but since World War II started, a few growers in the United States have undertaken production of this crop. A planting of the two species of the dish rag gourd was made at the United States Horticultural Station, Beltsville, Maryland, during 1942 in order to obtain information on time to maturity, yields, distance of planting, method of plant training, and removal of the rind and seed from the "sponge". Although the imported vegetable sponges are said to be principally of the species *Luffa cylindrica* some sponges of acceptable quality are of *L. aegyptiaca* (*L. acutangula*). This paper is based almost entirely on plantings of *L. aegyptiaca,* from lots of seed obtained through the Division of Plant Exploration and Introduction, Bureau of Plant Industry, United States Department of Agriculture. In this seed there were some *L. cylindrica* seeds that appeared as mixtures. The few lots of *L. cylindrica* available were of poor sponge quality but afforded some information on the adaptability of the plant in the Middle Atlantic States.

MATERIALS AND METHODS

The seeds were planted in the greenhouse in paper cups on May 18th. The cups were three-fourths filled with soil and the top quarter was filled with sand. On May 27, the plants were transplanted in the field in a light sandy loam soil. They were planted two to a hill, in hills 8 feet apart in three 8-foot rows 488 feet long.

One thousand pounds per acre of 5–8–5 fertilizer was drilled in the soil 2 weeks before planting. One week before planting ½ bushel of well rotted manure and ½ pound of superphosphate was worked into each hill. On August 9 a top dressing of 5–8–5 was applied at the rate of 1000 pounds per acre. On August 13, the plants were top dressed with nitrate of soda and hydrated lime at the rate of 1000 pounds per acre each. Muriate of potash was applied on this last date in the same manner but at the rate of 200 pounds per acre.

In the two outer rows, the plants were allowed to run on the ground. The center row was trained to a heavy wire trellis, consisting of three strands of wire 2, 3½ and 5½ feet from the ground, fastened to poles that were placed next to each hill. Every 50 feet a sturdy post was installed to give added support to the trellis.

The plants were sprayed with yellow cuprocide on August 13, 1942.

When flowering began, tags with blooming date were placed on many of the female flowers, and this was repeated at several intervals during the growing season up to 40 days before frost.

Fruits beginning to ripen were harvested and submerged in running water for 5 days to bring about fermentation. The rind or skin was rubbed off by hand and the seed and loose tissue were washed out. The vegetable sponge was then air dried.

RESULTS

A close-up view of *Luffa aegyptiaca* trained to a trellis is shown in Fig. 1.

Table I shows that the growing season was too short at Beltsville, Maryland, for the production of large yields of mature luffa fruit. The majority of fruit was still immature on the plants when further growth was prevented by frost which occurred on September 28, about 2 weeks earlier than normal. The few plants of the species *Luffa cylindrica* that appeared as mixtures among *L. aegyptiaca* bloomed later and the fruit also matured later than *L. aegyptiaca.*

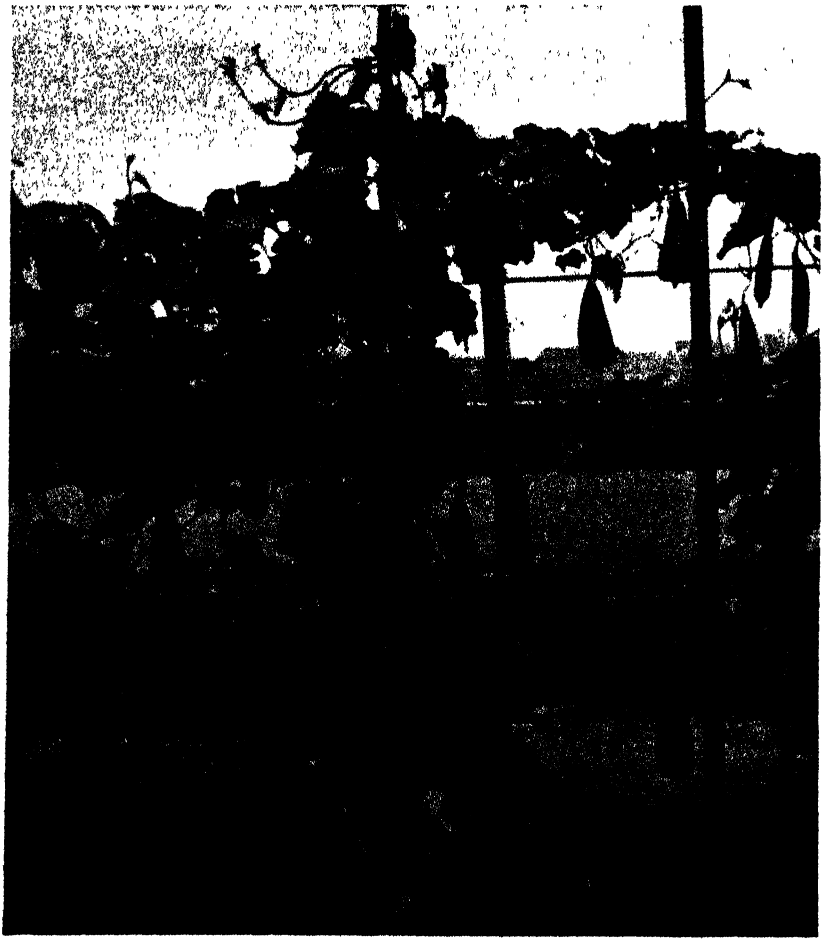

FIG. 1. *Luffa aegyptiaca* trained to a trellis.

TABLE I—FRUIT YIELDS OF *Luffa aegyptiaca*—COMPARISON BETWEEN GROUND AND TRELLIS SYSTEM OF GROWING

System	Number of Plants	Date Harvested: Sep 16 Number Fruit		Sep 24 Number Fruit		Oct 15* Number Fruit After Frost	Total Number Fruit* (0.09 Acre Per Plot)	Average Number Fruit Per Plant	Estimated Possible Yield Per Acre (Number Fruit)
		Sound	Rotted	Sound	Rotted				
Ground	93	52	8	123	10	2,258	2,451	26.4	27,233
Trellis.	94	77	1	171	0	2,054	2,303	24.5	25,589
Ground	90	56	9	0	7	2,001	2,073	23.0	23,033

*All fruits 6 inches or more in length were counted. Frost occurred September 28, two weeks earlier than usual.

Plants first began to bloom 52 days from date seed was planted; the majority of plants were in full bloom in 63 days. Out of a total of 363 tagged fruits, 16 per cent were ready for harvest between 41 and 49 days after flowering, 72 per cent were ready between 50 and 57 days, and 12 per cent between 58 to 68 days after flowering.

There was no real difference in fruit yield between ground and trellis-trained plants. Thirty-four rotted fruit occurred among those that matured on the ground before frost and only one rotted occurred among the fruit hanging from a trellis.

The ground and trellis systems had little effect on fruit shape in the short-fruited species *Luffa aegyptiaca*. With *L. cylindrica*, especially the long-fruited strains, most of the fruit on the ground became very crooked while the fruit hanging freely from the trellis was straight, as shown in Fig. 2.

Observations indicated that at Beltsville, Maryland, *Luffa aegyptiaca* would far outyield *L. cylindrica* because it was both earlier and more prolific.

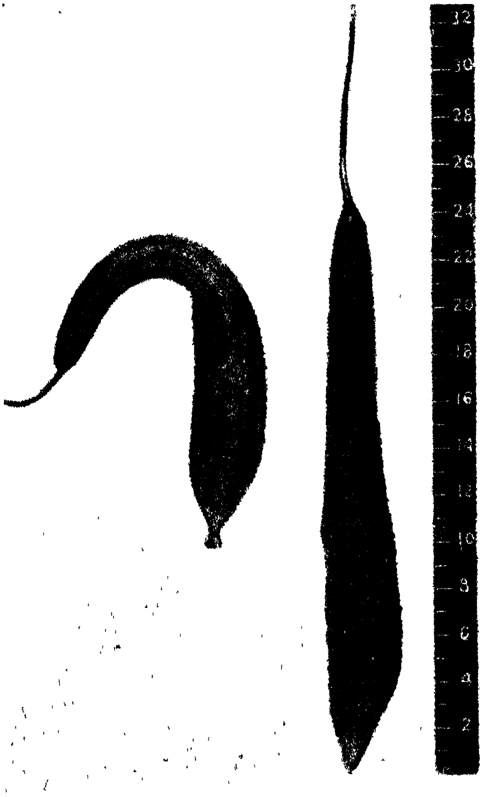

FIG. 2. *Luffa cylindrica*. Crooked fruit usual from plants trailing on the ground. Straight fruit always from plants grown on a trellis when hanging freely.

Harvesting is done

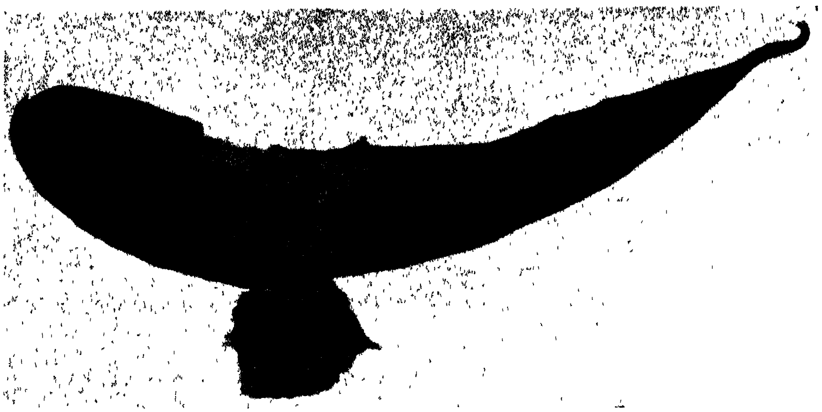

FIG. 3. *Luffa cylindrica*. After 5 days of water soaking the skin is easily removed. This strain possessed a coarse open fiber of low quality.

shortly after the rind or skin of the fruit turns brown when the fruit begins to feel soft. Before the fruit starts turning brown, it is very firm. After the fruit is harvested it is submerged in running water by a weight for 5 days at a temperature of about 70 degrees F to allow fermentation to take place. The rind of *Luffa cylindrica* then peels off easily as is shown in Fig. 3 and the seeds are washed out through the blossom end. *L. aegyptiaca* is much more difficult to "wash out". If the fruits are harvested in the green stage, the skin does not peel off but remains firmly attached to the underlying tissue. If the fruits are left on the vines until they get over-ripe, fungi attack them, striking through into the fibrovascular tissue and producing black spots on the sponge (Fig. 4). Fruits should be harvested at approximately weekly intervals to avoid over-maturity and resultant poor quality.

Toward the end of the season 90 properly matured fruit of *Luffa aegyptiaca* were submerged in water having a temperature of only 50 degrees F. After 2 weeks, it was still impossible to remove the skin due to lack of fermentation.

In a total of 164 air-dried *Luffa aegyptiaca* sponges, the weight ranged from 7 to 43 grams with an average of 20.2 grams. Length ranged from 6 to 14 inches with an average of 9¼ inches; stem-end diameter ranged from 1 to 2½ inches with an average of 1½ inches; blossom-end diameter ranged from 2 to 3½ inches with an average of 2¾ inches.

In a total of 10 air dried *Luffa cylindrica* sponges, the weight ranged from 8 to 54 grams with an average of 28.4 grams. Length ranged from 11 to 26 inches with an average of 20 inches. Stem-end diameter ranged from 1¼ to 4 inches with an average of 2½ inches.

DISCUSSION

It required approximately 63 days for the majority of plants to get in full bloom and an additional 57 days to mature individual fruits.

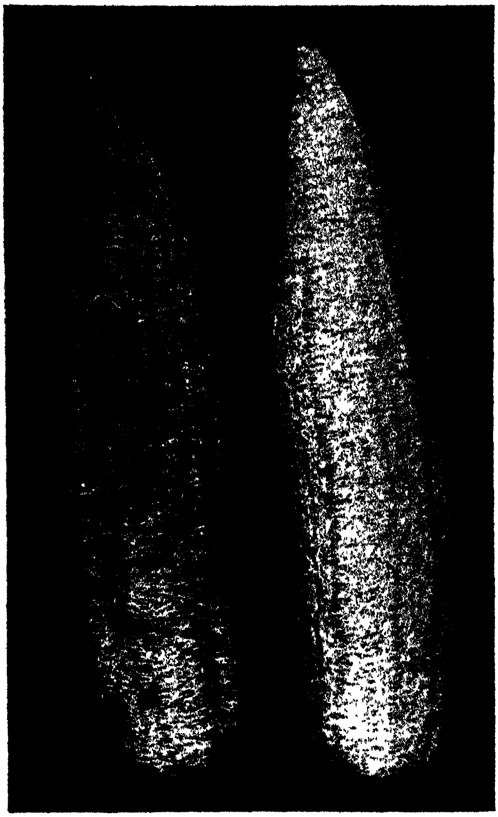

Fig. 4. *Luffa aegyptiaca.* Sponge on left from fruit that was allowed to turn completely brown before it was harvested. Sponge on right from fruit that had just begun to ripen and turn brown.

Howes (1) reports that in Japan the first blooms are pinched off, as well as the late summer blooms whose fruit will not have sufficient time to mature before frost. Our data showed that, as in Japan, the luffa requires a growing season of approximately 6 months. As the frost free season in 1942 at Beltsville was only 4½ months (normally 5 months) we were able to harvest only a small percentage of the total crop set on the vines.

In the part of Japan where the bulk of the luffa crop is grown, Howes (1) reports that *Luffa cylindrica* is sown approximately at the end of March. Planting is made 3 to 4 feet apart on ridges 3 to 4 feet apart. The entire area is covered with horizontal palings of wood or bamboo about 6 feet from the ground, supported by strong wooden posts. As the plants grow the young flexible stems are tied to the upright posts to assist in climbing. When high enough they are arranged between the wide meshes of the framework where they continue to develop of their own accord. The fruits are harvested in the autumn when the ends turn brown and the skin becomes soft to the touch. They are then submerged in running water for 5 days, after which the skin is removed easily by hand rubbing and the seed is easily shaken out. The sponges are then placed in the sun to dry. When completely dry, they are ready for the market. Morrison (2) reports that in Mexico the cleaned, wet, fibrous masses are strung on wires to dry in the shade — never in the sun. If dried too rapidly in the sun, the sponges become too brittle; if dried too slowly fungi are liable to damage the fiber.

At Beltsville, it was observed that the skin always came off easily from all of the fruit of *Luffa cylindrica* but there was considerable variation in *L. aegyptiaca.* In the case of P. I. No. 125825 the skin came off easier than in the other strains but never as easily as from the *L. cylindrica* fruits.

Both species of *Luffa* are apparently heavy feeders. In spite of the large amount of fertilizer and manure applied just before planting time, the leaves began to show visible signs of nitrogen deficiency during the second week of August after heavy rains. Muriate of potash and nitrate of soda were applied at that time.

Large numbers of squash bugs, honey bees, and bumble bees visited the flowers daily. Leaf diseases were completely absent. The crop was in a healthy growing condition up to the time of frost.

Although the figures in this paper are based entirely on *Luffa aegyptiaca* with but a few *L. cylindrica* plants scattered among them, it appears that *L. cylindrica* requires the same cultural treatments as *L. aegyptiaca.*

The varieties of *Luffa cylindrica* observed required a definitely longer growing season than those of *L. aegyptiaca* and the fruit were more susceptible to stem end rot when grown on the ground.

There are no data to show that the sponges of the *Luffa cylindrica* are consistently superior to *L. aegyptiaca* even though they are longer, and buyers pay more for the long sponges than for the shorter. The difference in ease of "washing out" the sponges of the two species is apparently very important.

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Results of Spraying Watermelons With a Copper Fungicide[1]

By John D. Hartman, *Purdue University, Lafayette, Ind.*

COMMERCIAL plantings of watermelons in southwestern Indiana are not sprayed for disease control. However, spraying, while not definitely recommended, has been suggested by Meier (5), Beattie (1) and others as a control measure for several watermelon diseases. Gardner (3) and Cardinell (2) have shown that copper sprays will control anthracnose on this crop to some extent. This disease, however, has been rarely or never present in Indiana during recent years, at least not on the fruit. Other defoliating diseases, including macrosporium leaf spot, have, on the contrary, been abundant. In 1939, by August 12, they removed all but the youngest leaves from watermelon plants at the Southwestern Indiana Horticultural Experimental Farm. At that time little of the crop had been harvested. This condition existed in spite of the fact that the plants had been dusted several times with an "insoluble" copper dust. The quality of fruit from these vines was very poor. All seven varieties grown in that year were about equally affected by the diseases. Spraying seemed to offer the only possibility for control during the years immediately following.

To investigate the practicability of spraying watermelons in southwestern Indiana an experiment was begun in 1940 and continued during 1941 and 1942.

FIELD OPERATIONS

All experiments were on Princeton or Elk fine sand. Each year plants of the variety Hawkesbury were started in veneer bands in coldframes. They were set in the field on May 23, in 1940, May 3, 1941, and May 16, 1942. The method of setting and, to some extent, the method of applying fertilizer were in accord with local custom. Just prior to setting, furrows 10 inches deep were opened with a listing plow at intervals corresponding to the distance between rows. Plants growing from a cube of packed manure were then regularly spaced in the bottoms of these furrows and soil drawn up around their crowns and over the manure. From 2 to 7 days after setting complete fertilizer was applied along the bottoms of these furrows, between plants. Later, of course, the furrows were completely filled. Each year the fertilizer provided 20 pounds of nitrogen per acre. Quantities of phosphoric acid were decreased from 180 pounds per acre in 1940, to 40 in 1941, and 24 in 1942. Correspondingly, the rate of applying potash was decreased from 150 to 100, to 30 pounds per acre. These changes were in line with general practice on the experimental farm, where there were indications that watermelons were not responding to large amounts of phosphorus and potash.

Plant spacing was 14 feet by 7 feet in 1940 and 12 by 8 feet in 1941 and 1942. Plots were 168 feet by 35 feet in 1940, 104 by 24 feet in 1941 and 153 by 24 feet in 1942. There were three plots of each of the two treatments in 1940, five in 1941 and seven in 1942.

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[1] Journal Paper No. 65, Purdue University Agricultural Experiment Station.

The natural tendency in cultivating watermelons is to drag the ends of the branches on the cultivator shovels and so to push them into narrow strips. In these experiments care was taken to avoid as much as possible such piling of the vines on top of each other, since it is obviously impractical to obtain good spray coverage or good aeration for a vine covered by several others. After about August 1, however, there were generally so many layers of vines over the whole plot that it was difficult to reach some of the leaves with the spray.

Each year plants were sprayed with a spray gun connected to the sprayer by a long hose. Roadways for the sprayers were left through the experimental area. On these, in 1941 and 1942, the rye cover crop was allowed to mature. This rye served as a windbreak to insure the young melon plants against damage or destruction by the usual sand storms of May and June. The roadways also facilitated collection and loading of melons at harvest. The spray gun used in 1940 and 1941 had only one nozzle. That used in 1942 had four nozzles in a row. The spray consisted of 1.5 pounds of an "insoluble" copper fungicide (about 50 per cent copper), 0.4 pound of a commercial spreader-sticker, and 8 pounds of cheap wheat flour in 100 gallons of water. Pressure was maintained at 300 to 350 pounds per square inch.

First applications were made about the middle of July, by which time the plants were setting fruit. The actual dates of spraying and the approximate amounts of spray applied were as follows:

	1940
July 18	90 gallons per acre
August 1	90 gallons per acre
August 20	190 gallons per acre
	1941
July 15	170 gallons per acre
July 29	170 gallons per acre
August 15	170 gallons per acre
	1942
July 13	320 gallons per acre
July 24	320 gallons per acre
August 18	180 gallons per acre

The harvesting season lasted from August 8 to October 2, 1940 from July 24 to August 25, 1941 and from August 1 to August 27, 1942. In 1940 only melons of No. 1 size and shape were pulled, but in 1941 and 1942 some of the smaller or somewhat imperfectly shaped melons were harvested also. These latter, were recorded as of other grades.

During the period August 1 to 13, 1941 the juice of representative ripe fruits from each plot was tested with a hand refractometer. This testing was repeated on fruits harvested from August 13 to 22. At both times the juice was taken from the seed region of the fruit.

CALCULATIONS ON DATA

In converting pounds per plot to pounds per acre, it was considered that one-ninth of any large area in watermelons, whether sprayed or not, ought to be reserved for roadways. One 6-foot roadway was allowed to every four 12-foot rows. Such roadways are, as previously explained, needed for growing temporary windbreaks and for hauling off melons, as well as for spraying.

In 1941 the plots were arranged in two tiers. In the north tier, plots 3 and 5, numbered regularly from east to west, were sprayed and plots 2 and 4 unsprayed. In analyzing the data the average yield of 1 and 3 was compared with the yield of 2 and the average for 3 and 5 with the yield for 4. The south tier was handled in the same way, although in this case the outer plots and the central one were of the unsprayed treatment. Thus in analyzing the data only four replicates were available. The data for 1942 were compiled in an analogous manner, but there were six replicates to be analyzed instead of four.

In summarizing the results for the three years the means for individual years were given equal weights. The standard error of the 3-year average difference was, therefore, one-third the square root of the sum of the squares of the standard errors for the three annual mean differences.

RAINFALL, LEAF DISEASES AND YIELDS

During recent years summer weather in southwestern Indiana has been characterized by frequency of light rains which wet the leaves and the upper inch of soil and by the infrequency of rains heavy enough to benefit plants materially. It was considered that only precipitation which totaled an inch on one day or on consecutive days helped growth to any extent. On the other hand, the number of days with some precipitation was rather an indication of the length of time when conditions were favorable for the dissemination of leaf diseases.

The year 1940 was especially dry. There were only 5 days with any precipitation in July, 6 days with precipitation in August, and 3 days with precipitation in September. During these months the only rains of any importance for plant growth occurred on July 11 and 12 (1.12 inches, total) and on September 24 and 25 (1.10 inches, total). Consequently, leaf diseases were never extremely destructive in 1940 and yields were not materially increased by spraying, as is shown in Table I. Plants continued to bear until they were plowed under in October.

The following year there were 11 days with some precipitation in July. On only one of these, July 2, was there a good rain, 1.47 inches. By August 10 leaf diseases had become exceedingly prevalent and had removed about 60 per cent of the foliage on unsprayed plots. There was a visible, but not remarkable, improvement in foliage retention attributable to spraying. Rain fell on only 5 days between the first of August and the end of the harvest season on August 26, but unsprayed plants did not recuperate and yields showed considerable differences in favor of the spray treatment. A rain of 2.02 inches on August 18 came too late to help plant growth and contributed rather to the final destruction of the foliage. July and August of 1941 were about as much like the same months in 1939, so far as rainfall and destructiveness of diseases were concerned, as the same season in two different years can be.

TABLE I—TOTAL AND EARLY YIELDS ON SPRAYED AND UNSPRAYED PLOTS

Treatments	Yields for First Third of Season (Pounds Per Acre)			Yields for Whole Season (Pounds Per Acre)		
	No. 1	Marketable	Total	No. 1	Marketable	Total
			Season of 1940			
Sprayed	7,694	7,694†	7,694†	24,046	24,046†	24,046†
Unsprayed	8,090	8,090†	8,090†	23,030	23,030†	23,030†
			Season of 1941			
Sprayed	2,835	3,192	3,262	12,448*	14,125*	14,338*
Unsprayed	1,797	2,585	2,733	8,630	10,882	11,154
			Season of 1942			
Sprayed	13,197	13,324	13,335	25,518	27,852	28,158
Unsprayed	13,694	13,799	13,799	24,673	25,624	25,677
			All Three Seasons			
Sprayed	7,909	8,070	8,097	20,670*	22,008	22,181*
Unsprayed	7,860	8,159	8,208	18,778	19,845	19,954

*Average yield on sprayed plots significantly greater than yields on unsprayed plots
†Only Number 1 melons were harvested in 1940.

July, 1942, with precipitation on 9 days, was nearly as wet as July, 1941; and August, 1942, had more rainy days (7) prior to harvest than August, 1941. Leaf diseases, however, developed somewhat more slowly in 1942 than in 1941. But, by August 22, differences in foliage retention between sprayed and unsprayed plots were more marked than at any time in 1941. Sprayed plots had approximately three times as many green leaves as unsprayed plots. Very likely, if a harvest had been made in September, a significant increase in yield due to spraying would have been obtained. However, the external and internal quality of all melons was rather poor by the first of September and so, although there were obviously more melons left on the sprayed areas than on the unsprayed, it did not, at the time, seem worthwhile to make another pulling.

QUALITY OF FRUIT

Refractometer studies on the juice of ripe melons in 1941 showed that early in the season there was no significant difference in quality due to spraying, but that later the quality of fruits from sprayed vines was far superior. Melons harvested from August 1 to 13 on the sprayed plots had the same refractive index as a 9.8 per cent sucrose solution, whereas the average reading on melons from unsprayed plots was 9.6. For the period from August 13 to August 22, however, the corresponding values were 9.2 and 7.7, respectively. The indicated superiority of melons taken from sprayed vines at the end of the season is highly significant statistically. Such a result was surely to be expected on account of the difference in functional leaf area and is in line with data obtained by Hartman and Gaylord (4) on the relation of leaf area to quality in muskmelons.

ECONOMIC CONSIDERATION

The cost of spraying with two spray guns and one machine would probably be about $3.50 to $4.00 per acre per spray at normal price and wage levels. This value was arrived at by taking into consideration labor, materials, depreciation of tractor and sprayer, and repairs. The spraying of a sufficient acreage to keep the sprayer working fairly steadily during the season was assumed. Thus the annual cost of spraying such as was done in these experiments should range from $10.50 to $12.00 per acre.

With farm prices for the whole season at the usual level of something like ½ cent per pound for No. 1 Indiana watermelons, spraying would have paid in the wet season of 1941, but not in 1940 and 1942. Since best prices are generally, but not always, obtained in the first third of the season slightly better financial returns might have been obtained from unsprayed areas in 1940 and 1942.

For the three years as a whole, no profit could be figured for spraying unless unusually high prices were obtained or a premium, over the market, was paid for quality. On the other hand for a watermelon business which required a dependable supply of quality fruit, spraying would be requisite.

SUMMARY

Experiments conducted for three years in Southwestern Indiana showed that spraying increased yields of No. 1 watermelons. At normal price levels, however, increases due to spraying were large enough to be profitable in only one year.

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Cultural Studies of Atropa Belladonna

By E. N. STILLINGS and ALEX LAURIE, *Ohio Agricultural Experiment Station, Wooster, Ohio*

A COÖPERATIVE project between the United States Department of Agriculture, the Ohio Agricultural Experiment Station, the College of Pharmacy, and the College of Veterinary Medicine was started in January, 1942, dealing with the culture of several medicinal plants. The present progress report deals with belladonna only. The object of the project was to determine the best and simplest methods of culture of belladonna so that the crop could be handled satisfactorily by growers in Ohio.

Studies were made on germination of seed in different media, temperatures, and water relations. Methods of handling plants, distances of planting, light and soil nutrition were a part of subsequent studies both in the greenhouse and outdoors. Harvesting, curing, and assaying[1] problems likewise formed a part of the project.

SEED GERMINATION

Seed was sown March 6, germinated in 13 to 17 days and seedlings were ready to be pricked off in 25 to 30 days. The temperature maintained was 60 degrees F. The mediums used were: (a) one-third silt loam, one-third sand, one-third sphagnum peat; (b) one-half silt loam, one-half sand; (c) one-half sand, one-half peat; (d) one-half sand, one-half silt loam with a covering of sphagnum moss; and (e) sphagnum peat.

Each mixture was divided into three sections: (a) watered overhead; (b) subirrigated with one glass wick to a flat; and (c) subirrigated with two glass wicks to a flat.

Table I shows the percentage of germination. No significant differ-

TABLE I—BELLADONNA SEED GERMINATION TESTS

Medium	Treatment	Germination (Per Cent)
Soil, sand, peat	Two wicks One wick Overhead	47 42 29
Soil, sand	Two wicks One wick Overhead	41 21 36
Sand, peat	Two wicks One wick Overhead	43 35 48
Soil, sand, sphagnum	Two wicks One wick Overhead	45 37 42
Peat	Two wicks One wick Overhead	43 35 45

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[1] This was done under the direction of Dr. L. D. Hiner of College of Pharmacy Ohio State University and Willis Brewer, graduate assistant.

ences were observed between the mediums, or between treatments. However, the percentages of germination in all treatments were higher than normal.

TRANSPLANTING

The plants used for studies in the greenhouse and outdoors were treated in three ways: (a) set in flats 2 inches apart; (b) potted in 2½-inch pots; and (c) set in wooden bands. The test showed that no differences resulted after planting provided it were done late in April or early May. Later plantings indicated that either bands or pots should be used. Hence a mechanical planter is feasible if planting is done early enough to insure proper establishment of plants before hot weather.

LIGHT

To determine the effect of light intensity upon the production of belladonna, plants were grown under Aster cloth (35 per cent reduction of intensity), lath house (50 per cent reduction, shifting shade), and outdoors without protection. The soils used were similar in nature and composition. Table II shows the results.

TABLE II—PRODUCTION OF BELLADONNA UNDER VARIOUS LIGHT CONDITIONS (SPACING 12 BY 12 INCHES)

Treatment	Number of Crops Harvested	Grams* (Per Plant)	Pounds* (Per Acre)
Normal	Four	63.4	6,086
Cloth house	Four	57.1	5,481
Lath house	Four	26.5	2,544

*Dried and ready for assays

Reduction in light intensity is detrimental to plant growth. Furthermore, the assays showed that higher percentages of alkaloids were developed under conditions of high light intensity.

GREENHOUSE VS OUTDOOR CULTURE

Comparative plots were planted in the greenhouse and outdoors, the soil being similar in both plots. Those grown in the greenhouse were in an atmosphere of higher humidity than those outside. Both plots were planted May 15.

TABLE III—PRODUCTION OF BELLADONNA — GREENHOUSE VS OUTDOOR GROWN

Dates of Harvests	Pounds Per Acre	
	Greenhouse 12 Inches by 12 Inches	Outdoors 12 Inches by 12 Inches
June 15	904	
July 6		1,276
July 21	880	
August 5		1,505
August 18	528	
September 1		1,382
September 7	880	
October 12	872	1,862
Totals	4,064	6,085

Though the greenhouse plot produced one more harvest than the outdoor plot, during the same period of time the outdoor plot produced more material. Whether or not the plants in the greenhouse will continue to grow normally during the winter remains to be seen.

NUTRITION

To indicate something of the nutritional requirements for optimum yield of belladonna, plots were planted in a sandy nursery soil. Each plot, planted May 14, originally contained 32 plants.

Eight different nutrition levels, replicated varying the concentration of nitrogen, potassium, and phosphorus, were established. Each variation was run in soils at pH 6.5 to 7.5 and 5.5 to 6.5. Two plots, the soil varying in pH as just mentioned, were treated with a starter solution, 6 gallons per 100 square feet, 2 weeks after planting.

The concentration of available nutrients was as follows—Nitrogen: high, 50 to 100 parts per million; low, 10 to 50 parts per million. Potassium: high, 20 to 40 parts per million; low, 5 to 20 parts per million. Phosphorus: high, 5 to 10 parts per million; low, 1 to 3 parts per million.

The soils were tested every 10 to 12 days and applications made accordingly. Those plots which contained low concentrations were carried at the middle or below the middle of the range listed. Those which contained high concentrations were maintained in the lower half of the range listed, with the exception of potassium. Due to the nature of the soil and the frequent rains it was practically impossible to maintain a high level of this nutrient. To the high potassium plots, therefore, frequent applications were made; to the low potassium plots very few applications were made.

TABLE IV—BELLADONNA PRODUCTION (VARIATIONS IN AVAILABLE N, P, AND K, AND IN SOIL pH)

Treatment	Pounds Per Acre (12 Inches by 12 Inches)	
	pH 6.5–7.5	pH 5.5–6.5
Starter solution	4,022	4,157
High N, P, and K	5,981	5,712
Low N, P, and K	3,312	3,254
Low N, high P and K	5,203	4,800
Low N and P, High K	3,532	4,041
High N, Low P and K	3,897	6,570
High N and K, Low P	5,424	5,625
Low N and K, High P	2,918	4,406
High N and P, Low K	6,038	5,366

It is evident that high concentrations of available N increased production. There is likewise some indication that high P and K produced higher yields.

Though all material from these plots assayed standard quality, that from plots of pH 5.5 to 6.5 yielded higher quantities of alkaloids than did that from the higher pH plots.

Production figures were obtained by harvesting leaves and small stems (under 10 millimeters in diameter) when the plants were flowering.

Polyploidy in the Easter Lily

By S. L. EMSWELLER and D. V. LUMSDEN,[1] *U. S. Department of Agriculture, Beltsville, Md.*

IN an earlier paper by Emsweller and Ruttle (3), a brief report was given on the production of tetraploid Easter lilies (*Lilium longiflorum*) by the use of colchicine. The present paper is a more detailed report on these lilies which have now bloomed and been compared with diploids of the same clon. Only a morphological comparison between the tetraploid and diploid plants is presented in this paper. Several interesting mixoploid and aneuploid plants were also found and will be discussed in a cytological paper now being prepared.

MATERIALS AND METHODS

The lilies used in these experiments were all members of a clon of the Creole Easter lily (*Lilium longiflorum*). The bulbs were given to us by Dr. Fred Cochran of the University of Louisiana at Baton Rouge, Louisiana. He had developed the clon by scaling a large bulb and continuing the propagation for several years.

The diploid chromosome number of *Lilium longiflorum* is 24. The Creole lily clon was found to be diploid. Two methods were tried to induce doubling of the chromosomes. The first was the one reported by Emsweller and Brierley (2), in which the growing point of the elongating flowering stem of *L. formosanum* was treated with several concentrations of colchicine prior to flower bud differentiation. This treatment was unsuccessful with *L. longiflorum*, although other concentrations of colchicine or lengths of exposure might have given results similar to those secured with *L. formosanum*.

Within a few weeks after Easter lily bulb scales are removed and planted they normally form from one to three small bulblets at the base of the scale. Propagation of Easter lilies by this method has been in general use for many years. The second method of treatment, which proved successful with the Creole, consisted in soaking freshly detached bulb scales in aqueous solutions of colchicine. Following treatment the scales were placed base down in flats of coarse sand. About three-fourths of the scale was imbedded in the sand. As soon as bulblets and roots were formed, the scales with attached bulblets were planted in soil in greenhouse benches.

RESULTS

The treatments used and results secured are shown in Table I.

A total of 1,250 scales were treated, 50 scales in each treatment, but less than half produced bulblets. The 258 plants included in this table are the only ones examined cytologically with the exception of the mixoploids and aneuploids mentioned earlier. Chromosome counts were made from acetocarmine smears of root tips of all tetraploids and most of the diploids, and confirmed in all instances by examinations of either pollen mother cells, or pollen grains and flowers. The 123

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[1] Now on military furlough.

TABLE I—RESULTS OF TREATING EASTER LILY SCALES IN COLCHICINE SOLUTION

Treatment	Period of Immersion									
	1 Hour		2 Hours		3 Hours		24 Hours		Totals	
	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid	Diploid
H_2O	0	All	0	All	0	All	0	All	0	All
Colchicine										
0.05 per cent	—	—	—	—	—	—	1	7	1	7
0.10 per cent	9	15	15	9	3	4	—	—	27	28
0.20 per cent	13	6	13	3	13	8	—	—	39	17
0.50 per cent	10	11	12	19	9	8	—	—	31	38
1.00 per cent	8	17	10	26	7	2	—	—	25	45
Totals	40	49	50	57	32	22	1	7	123	135

tetraploids among the 258 plants examined does not mean that the percentage of tetraploids in the entire population was actually this high. Because of the thicker leaves and larger stomata of tetraploids it was possible to select polyploid plants with an accuracy of about 90 per cent, and there were many plants not examined cytologically

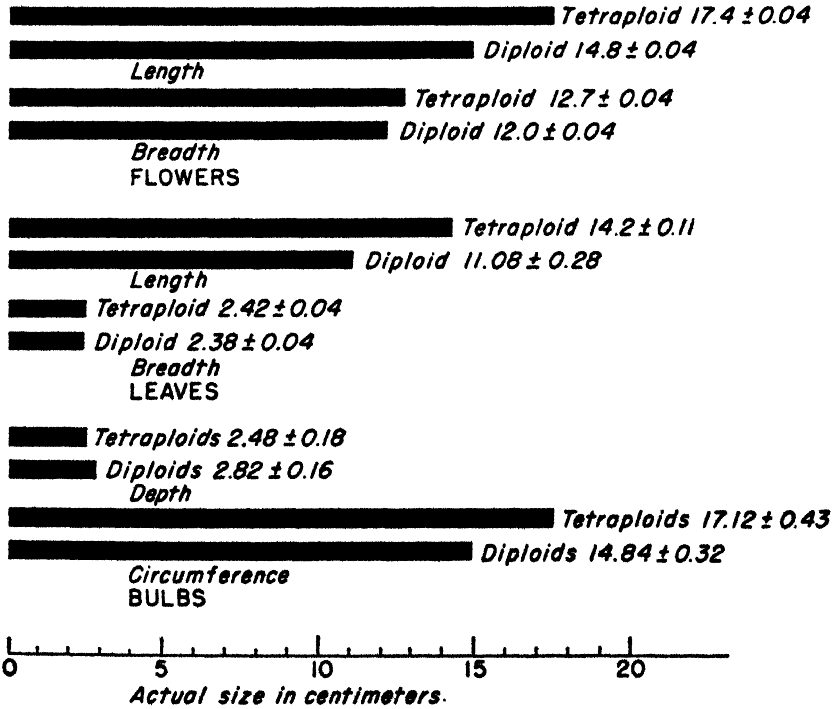

FIG. 1. Comparative measurements of flowers, leaves and bulbs of tetraploid and diploid Creole lilies.

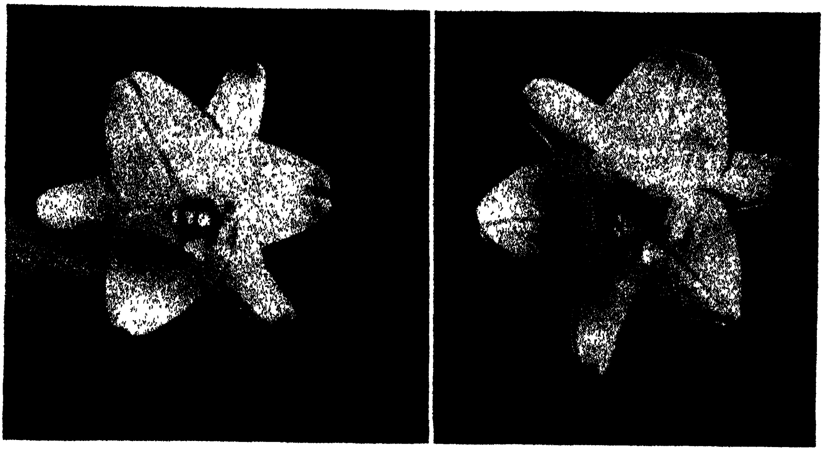

FIG. 2. Diploid Creole flower (left), and tetraploid (right).

that were probably diploid. It is of interest to note that all treatments were effective at the 1-, 2-, and 3-hour intervals. The .05 per cent concentration was used for only the one interval of 24 hours.

Comparative measurements of the flowers, leaves, and bulbs of the tetraploids and diploids are shown in Fig. 1.

The flowers of the tetraploids were 15 per cent longer but only 5.6 per cent broader than the diploids, the mean measurements being secured from 50 flowers of each type (Fig. 2). These differences are statistically significant. While the tetraploid flowers were actually broader than the diploids, the ratio of their breadth to length was less than the same ratio in the diploid. This gave the tetraploid flowers an appearance of being less widely open than the diploids. This apparent failure of the tetraploid flowers to open may have been due to the thickness of the petals which gave the flower a sturdy structure. This increase in petal thickness is a desirable feature in the Easter lily where a heavy flower of good "substance" is very desirable. Whether or not the over-all increase in flower size will be acceptable to the trade remains to be ascertained.

The leaves of the tetraploids were significantly longer than those of the diploids, but there was no difference in leaf breadth. Measurements were all made on the fifth leaf below the inflorescence, and 50 leaves each of the tetraploid and diploid were used. Leaf thickness was also considerably increased as a result of tetraploidy, which made it possible to select polyploids with a high degree of accuracy.

The bulb measurements show the tetraploid bulbs to be significantly flatter and of a greater circumference than the diploids. The measurements were made on 100 tetraploid and 128 diploid bulbs, all grown under the same conditions of environment. The greater diameter of the tetraploid bulbs accentuates their slightly flattened appearance and makes it possible to sort out a mixture of the two types of bulbs with a fair degree of accuracy.

Under normal conditions the Creole lily is self-incompatible (1), but crosses readily with most of the other forms of *Lilium longiflorum*. The tetraploids are also sterile and no seed was secured from crossing them with a number of diploid forms. The lilies may be increased by scaling, however, and this is being done as rapidly as possible.

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The Influence of Storage Temperature on Forcing Performance of Creole Easter Lilies

By NEIL W. STUART, *United States Department of Agriculture, Beltsville, Md.*

ABSTRACT

This material will be published in full in the *Florists' Review*.

EASTER LILIES of the Creole variety grown in Louisiana were used in this test. The bulbs were dug July 20 to 25, 1941, allowed to dry off in common storage for 1 week, and then shipped to the Bureau of Plant Industry Station, Beltsville, Maryland. On August 12 the bulbs were sorted into six comparable lots of 125 bulbs each (all bulbs being between 7 and 8 inches in circumference), packed in moist peat, and stored at 36, 40, 45, 50, 55, and 59 degrees F. One lot of 25 bulbs was potted and brought to the greenhouse at once. At intervals of 2, 4, 6, 8, and 10 weeks, 25 bulbs were withdrawn from each storage temperature and potted in 6-inch pots containing composted soil. The pots were arranged in five blocks on ground beds in a greenhouse maintained at a night temperature of 55 degrees F with day temperature of 60 to 65 degrees. Data were obtained as to size of each bulb, date of emergence from the soil, date of first bloom, size of bloom, height of plant, number of leaves, and presence of virus. These data support the following conclusions:

1. Storage at any of these temperatures for any interval reduced the number of days required for emergence and for first bloom below the number required by unstored bulbs.
2. This acceleration in emergence and in blooming was greatest in bulbs stored at 45 and 50 degrees F.
3. Acceleration in blooming was accompanied by a reduction in number of leaves and blooms per plant.
4. Maximum acceleration consistent with moderate reduction in flowers was accompanied by storage for 6 weeks at 45 degrees F.
5. Storage at temperatures above 50 degrees F for more than 4 weeks reduced the number of blooms per plant without a compensating acceleration in blooming time.
6. Least reduction in flowers per plant was produced by storage at 36 degrees F.
7. Plants from bulbs stored at temperatures below 50 degrees F were taller than those from bulbs stored at temperatures of 50 degrees or higher.
8. Bloom size was affected by the number of days to blooming and by the number of blooms per plant, being largest on plants requiring the least number of days to bloom or those having the fewest flowers per plant.
9. Presence of necrotic type virus reduced forcing performance of the bulbs regardless of storage temperature.

Flower Development in Creole Easter Lilies Stored at Various Temperatures

By S. L. EMSWELLER and R. L. PRYOR, *U. S. Department of Agriculture, Beltsville, Md.*

IN a series of papers by Brierley (1, 2), and Brierley and Curtis (3), it was shown that flowering in the American grown Creole Easter lily (*Lilium longiflorum*) may be hastened by cool storage. The storage temperatures used were 0, 2.2, 4.4, and 10 degrees C. Various storage periods were used, and of the combinations tested 10 degrees C for 5 weeks gave the greatest stimulation to early blooming.

These results, and some nutrition work about to be undertaken with cool-stored Creole lily bulbs, made it advisable to ascertain when flower buds were differentiated in these lilies following storage at different temperatures. Pfeiffer's work (4) with imported Easter lilies had indicated some variation in time of bud differentiation between the varieties Giganteum and Harrisii following storage at different temperatures. Her work, however, was chiefly concerned with the ontogeny of the floral axis rather than with time of bud differentiation as related to forcing. Our observations on the morphological details of floral development are in agreement with Pfeiffer's, and are not presented in this paper.

MATERIALS AND METHODS

The Creole lily bulbs for these experiments were grown in Louisiana and furnished through the courtesy of Vaughan's Seed Store. They were dug July 1, 1940, and received at the Bureau of Plant Industry Station, Beltsville, Maryland, July 10. The bulbs were immediately divided into three lots of 300 each and stored at 0, 10 degrees C, and in the bulb storage house where the temperature fluctuated from about 21 to 29 degrees C at that time of year. The temperature of the bulb house dropped during the fall and winter to as low as 4.4 degrees, but the mean temperature during the colder months was around 10 to 12 degrees C.

The growing points of the lilies were prepared for preliminary examination before they emerged from the bulb by carefully removing all scales except the five or six small ones immediately surrounding the meristem region. Dissection was then completed and examination made under wide field binoculars. Growing plants were handled in essentially the same way except that leaves had to be removed instead of bulb scales. At each sampling the stem lengths were measured from the top of the bulb to the highest point on the growing plant. Five bulbs from each storage treatment were collected and examined each week for six consecutive weeks from July 10 to August 21. The bulbs then remaining in each storage were divided into two lots of 120 each. One of the lots from each treatment was planted in 6-inch pots and placed in a greenhouse where the temperature was maintained at about 12 to 13 degrees C at night and at 15 to 18 degrees C during the day. The second lot in each treatment was continued in storage. Samples from both planted and stored bulbs receiving each storage treatment were collected for observation at various intervals.

OBSERVATIONS ON BULBS KEPT IN STORAGE

Flower buds were not differentiated in any of the bulbs while in storage from July 10, 1940, to February 19, 1941. By this time, however, those stored in the bulb house at 21 to 29 degrees C, with lower subsequent temperatures, had all produced a considerable amount of etiolated stem growth (15 to 20 centimeters). No growth occurred at 0 degree C and very little (3 to 4 centimeters) at 10 degrees C. No further observations were made on stored bulbs, as they were used for other purposes.

OBSERVATIONS OF PLANTED BULBS

The stems of planted bulbs from the 10 degrees C treatment began to emerge from the soil 15 days after potting. They appeared 7 to 10 days later in the 0 and the 21 to 29 degrees C lots. The data are summarized in Table I. During the first 4 weeks after planting, from August 21 to September 18, the growing points exhibited no visible changes except for a rounding off which appeared more pronounced in those bulbs that had been stored at 10 degrees C (Fig. 1, A). The apex of the flowering stem is shown here surrounded by young leaves. No indications of flower primordia are present at this stage of development. By September 18 the average length of flowering stem was 3.8 centimeters on bulbs stored at 0 degrees C, 15.2 centimeters on those stored at 10 degrees C, and 4.9 centimeters on those at 21 to 29 degrees C.

TABLE I—INFLUENCE OF PREPLANTING STORAGE FOR SIX WEEKS ON GROWTH, FLOWER BUD DIFFERENTIATION, AND TIME OF FLOWERING OF CREOLE EASTER LILIES (BULBS PLACED IN STORAGE JULY 10; PLANTED AUGUST 21, 1940)

Date of Sampling	Storage Treatment (Degrees C)	Length of Flowering Stem (Cm)	Flower Buds Present or Absent	Appearance of Growing Point (Reference to Figures)
Sep 11, 1940	10	7.8	–	1 A
Sep 18, 1940	10	15.2	–	1 A
Sep 18, 1940	0	3.8	–	1 A
Sep 18, 1940	21 to 29	4.9	–	1 A
Sep 25, 1940	10	24.9	+	1 B
Oct 2, 1940	10	47.8	+	1 C
Oct 9, 1940	10	42.1	+	1 D
Oct 16, 1940	10	40.1	+	1 E
Oct 23, 1940	10	53.3	+	1 F
Oct 30, 1940	10	52.8	+	2 A*
Dec 11, 1940	0	40.6	+	2 B
Dec 19, 1940	0	44.4	+	2 C
Jan 15, 1941	0	46.3	+	2 D†
Jan 29, 1941	21 to 29	45.7	+	2 E
Feb 19, 1941	21 to 29	47.0	+	2 F‡

*Blooming date November 15, 1940.
†Blooming date March 21, 1941.
‡Blooming date April 27, 1941.

Bud differentiation on the plants in the 0 degree C lot was not visible until December 11 (Fig. 2, B), 163 days after digging and

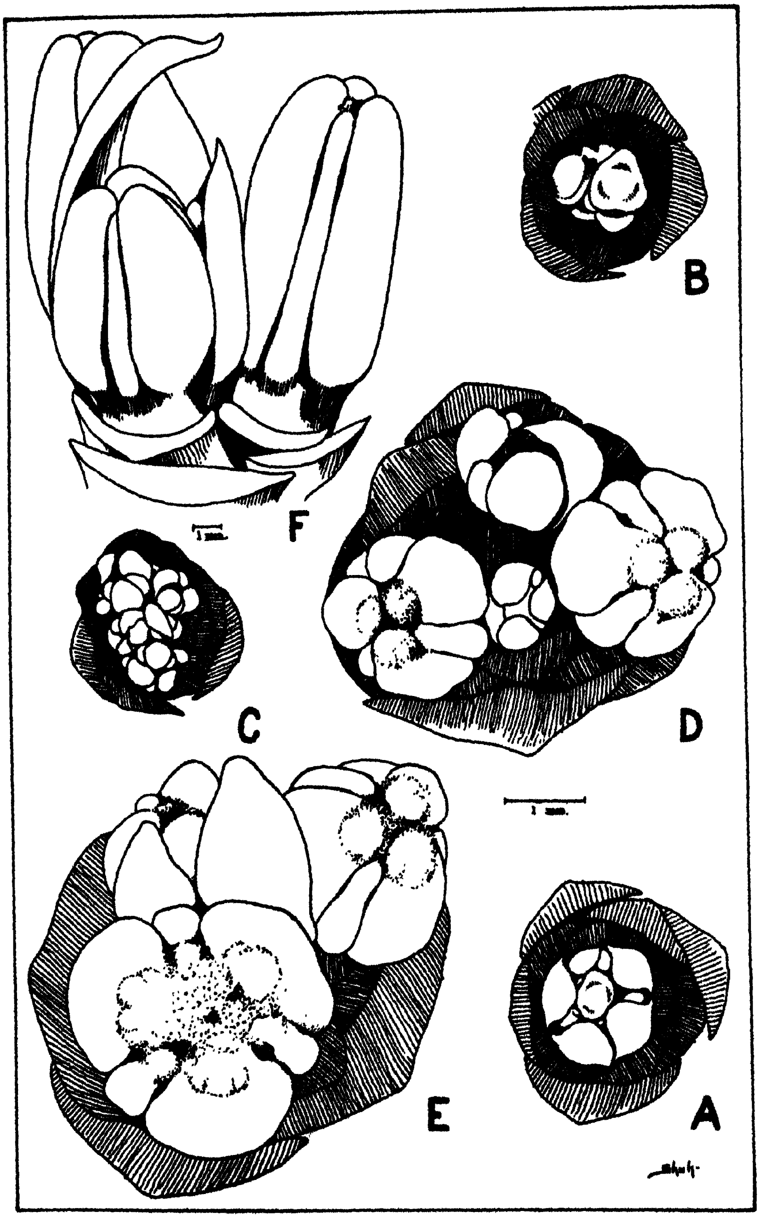

FIG. 1. Flower bud development in *Lilium longiflorum* var. Creole. A, Typical growing point of all bulbs examined after storage for 6 weeks at 0, 10, or 21 to 29 degrees C; also typical of growing plants for 25 or 35 days after planting on August 21. B to F, stages of development of the plants receiving 10 degrees C storage treatment: B, grown until September 25; C, October 2; D, October 9; E, October 16; and F, October 23. (C-F drawn to smallest scale.)

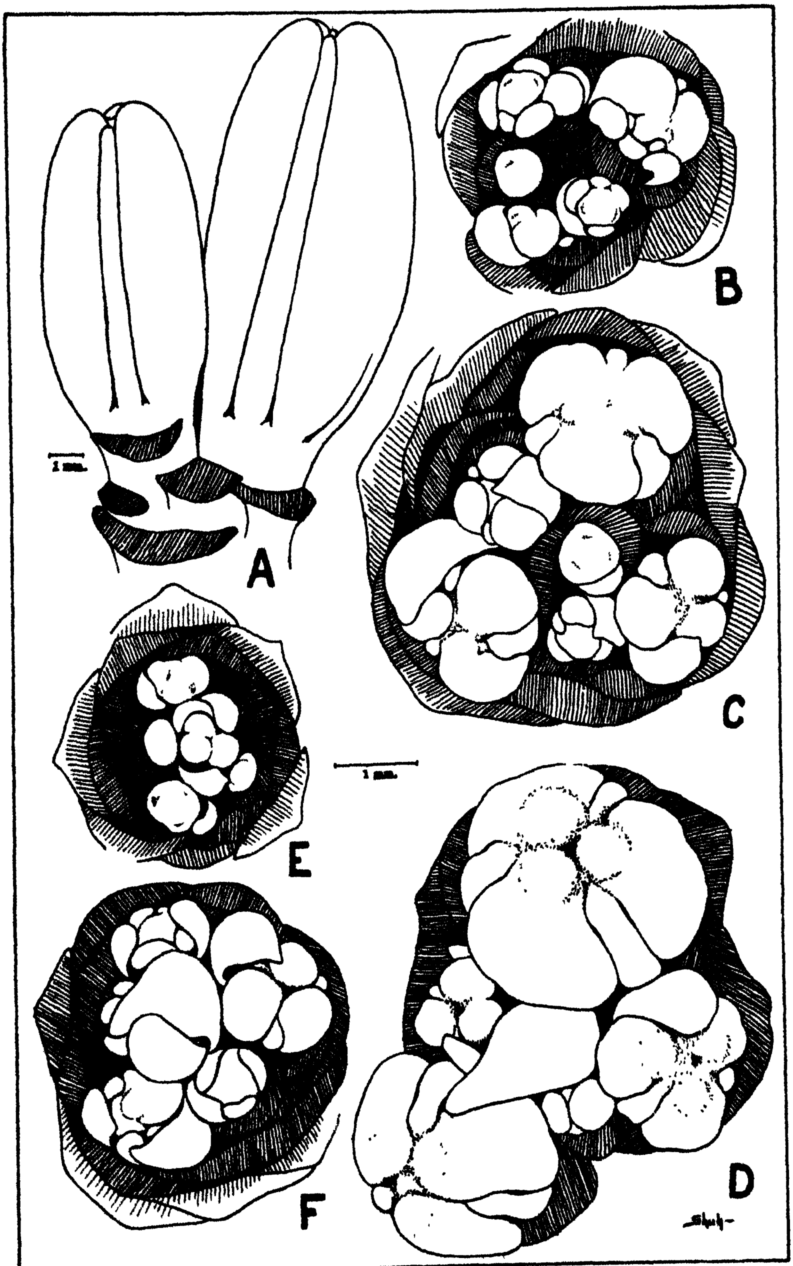

FIG. 2. Stages in bud development. A, 10 degrees C storage lot, grown until October 30. B-D, 0 degree C storage lot: B, grown until December 11; C, December 19; D, January 15. E and F, 21 degrees to 29 degrees C storage lot: E, grown until January 29; F, February 19. (B-F drawn to larger scale than A.)

112 days after planting. Prior to December 11, all growing points from the bulbs stored at 0 degree C were very similar to the stage shown in Fig. 1, A. When the first flower buds appeared in this treatment, however, only one plant in the five examined had progressed this far. A week later, on December 19, only two plants were collected and both had well-developed buds (Fig. 2, C). These two plants were 40.6 and 48.2 centimeters tall, respectively. The next three collections of two plants each, made December 26, January 2, and January 8, had no flower buds. The stems of all these plants, however, were shorter than those that had buds on December 11 and 19. The tallest was 38.1 centimeters as compared to 40.6 centimeters for the December 11 plant. On January 15 the two plants examined had well-developed buds (Fig. 2, D). The remaining plants were allowed to flower.

The first evidence of flower buds from bulbs stored at 10 degrees C was found on September 25 in three of the five plants (Fig. 1, B). This was 86 days after digging and 35 days after planting, and was 77 days earlier than the appearance of buds on the lot stored at 0 degree C. Two young flower buds were found on the particular sample from which the drawing was made; in the apical bud the three outer perianth lobes were just forming. The average stem length of the three plants with flower buds was 24.9 centimeters, while the other two plants were only 14 and 16 centimeters tall. At the next collection from this treatment, on October 2, all five plants had well-developed flower buds as shown in Fig. 1, C, and the average length of stem was 47.8 centimeters. The growing points secured from this same treatment on five succeeding weeks are shown in Figs. 1, B, C, D, E, F, and 2, A. From the time the buds were just starting until they could easily be seen the stem length increased from 24.9 to 52.8 centimeters. No further collections were made from the plants derived from bulbs stored at 10 degrees C.

The plants produced by the bulbs stored at 21 to 29 degrees C differentiated flower buds on January 29, 212 days after digging and 161 days after planting. Prior to this date their growing points were all very similar to Fig. 1, A. The flower stem had been elongating, however, and was 45.7 centimeters in height when the first flower buds were formed, which was about 5 centimeters more than the stem of the 0 degree C lot when it first differentiated buds. Plants from both the lowest and highest storage temperatures produced considerably more stem growth than those from 10 degrees C storage before flower buds formed. The last collection was made on February 19, and the stage of development of flower buds is shown in Fig. 2, F.

TIME OF FLOWERING

Five plants each from the 0 and 21 to 29 degrees C storage treatments and one from the bulbs stored at 10 degrees C were allowed to continue growing until they flowered. The five plants in the 0 degree C treatment were in flower from March 21 to 28, which was 212 to 219 days after planting. The 10 degrees C plant bloomed on November 11, just 86 days from planting. Plants from the 21 to 29 degrees C storage were in flower from April 24 to May 1, or in 246 to 253 days.

Although few plants were allowed to flower in each treatment, the periods when they did bloom are in close agreement with data from other experiments in which the same temperatures and comparable intervals of storage were used.

DISCUSSION

Many of the data presented in this paper, especially the dates of flowering, are not representative of Easter lilies in general. Other varieties and even Creole dug at different times or from other sections would not necessarily behave the same.

While the average height reached by flowering stems before buds were differentiated varied in the three treatments, it is clear that flower buds are not normally formed in the Creole Easter lily until the plant has a well-developed stem. Even in the most favorable treatment flower buds were not found until 35 days after planting, when the stems had reached an average height of 25 centimeters. The first buds were found in the 0 degree C treatment when the flowering stems were about 40 centimeters tall, and in the 21 to 29 degrees C lot when the stems averaged about 45 centimeters. A reduction in height of Easter lilies following 10 degrees C storage as compared to storage at lower temperatures and to no preplanting storage, was shown by Brierley and Curtis (3), and has always occurred in our forcing experiments. Probably this reduction is the direct result of early differentiation of flower buds.

The intervals from planting to flower bud formation and from bud formation to flowering were materially shortened by storage at 10 degrees C as compared to 0 degree C, or to 21 to 29 degrees C. Following 10 degrees C storage these periods were 35 days and 51 days; following 0 degree C, 112 days and 100 days; and following 21 to 29 degrees C they were 162 days and 88 days. The stimulating effect of the 6-weeks' storage at 10 degrees C is apparent in shortening both the period from planting to flower bud formation and the time required for development of differentiated buds into fully-opened flowers.

SUMMARY

Flower buds, in Creole Easter lily bulbs dug July 1, were not differentiated while the bulbs were kept in storage from July 10 to February 19 at 0 and 10 degrees C and in the bulb house.

Flower buds did not appear until the flowering stem had reached a height of about 25 centimeters in the bulbs stored for 6 weeks at 10 degrees C and not until stems were 40 centimeters and 45 centimeters on the 0, and the 21 to 29 degrees C lots.

The 10 degrees C storage treatment for 6 weeks resulted in flower buds 35 days after planting, and flowers in 86 days. The 0 degree C lot developed flower buds 112 days after planting, and flowers in 212 to 219 days. The high temperature treatment of 21 to 29 degrees C gave buds 161 days after planting, and flowers in 246 to 253 days.

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Controlling Time of Blooming of Chrysanthemums by the Use of Lights

By NEIL W. STUART, *U. S. Department of Agriculture, Beltsville, Md.*

ABSTRACT

This material will be published in full in the *Bulletin of the Chrysanthemum Society of America.*

EXPERIMENTS carried on during the last two years at the Bureau of Plant Industry Station, Beltsville, Maryland, have conclusively demonstrated a new and highly successful method of delaying the blooming time of greenhouse chrysanthemums. It is well known that chrysanthemums are short-day plants, forming buds when the length of the night exceeds that of the day. Attempts to delay bud formation by the use of lights at the end of the day have not been generally successful in a commercial way due to cost and uncertainty of blossoming time.

The new method is based in principle on results obtained by Borthwick and Parker of this Station in their work with soybeans. These workers found that interruption of the dark period near its mid-point with a short interval of light prevented bud formation.

In the season of 1941–42, 2,000 chrysanthemum plants of four commercial varieties were grown to maturity. Plants of each variety were exposed to four variations of light treatment consisting in various interruptions during the night. The light intensity varied from 16 to several 100-foot candles at different positions in the bench. These treatments were as follows:

1. Light supplied for 5-minute periods at 8, 10, 12, 2, 4 and 6 o'clock during the night, or 30 minutes in all.
2. 10 minutes of light at midnight.
3. 30 minutes of light at midnight.
4. 60 minutes of light at midnight.

The treatments were started August 1, 1941. At regular intervals of 1 or 2 weeks, plants from each treatment were removed to the naturally lighted control benches and replaced with plants from these benches. This was done in order to establish the effect of light application at different stages of bud and blossom development. As the flowers became commercially mature they were harvested and records made as to time of blooming, size of plant, number of flowers and buds, and quality of flowers. An analysis of these data substantiates the following partial summary:

1. Interrupting the dark period with 30 to 60 minutes of light is a successful means of delaying flowering in chrysanthemums for 2 to 3 months after normal flowering time for the variety.

2. This delay in flowering is accompanied by no reduction in quality or quantity of flowers. As a result, growers will be able to flower their very best varieties over longer periods.

3. By use of the new method it will be possible to produce high quality chrysanthemum blooms during January and February. This has not been possible with means previously available.

4. Use of a 30-minute light period in the night is far less costly and more effective than added periods of 2 to 3 hours at the end of the day, as formerly used.

5. With the new method, it is possible to completely prevent bud formation until desired. Consequently, by discontinuing the use of lights with various lots at successive dates, it is possible to obtain a continuous succession of bloom. It is not necessary—in fact, it is undesirable—to use lights after the buds are formed.

6. It has been established that the light treatment, to be most effective, must be started at least 10 days before the first visible sign of bud formation.

During the 1942–43 season 100 plants each of the 10 most important commercial varieties are being grown under the new system of flower control. All of these varieties are responding in the same manner as those tested last year. Included in this year's test are three standard or large-flowered varieties grown with one flower per stem. Two of these varieties, Mrs. David Roy and Orchid Queen, are the best available in their color. They normally bloom about November 12, but florists have reported a demand for these varieties long after they are past their blooming season. By means of the light treatment it will be possible to have them in flower for more than 2 months.

By use of this new method of light treatment and with some modification in growing procedure, superior pot plants may easily be produced for Christmas or other holidays.

A full report dealing with all phases of the experiments conducted during the two seasons will be prepared at the conclusion of the present tests.

Flower Bud Differentiation in Cattleya Pinole

By Eleanor Johnson and Alex Laurie, *Ohio State University, Columbus, Ohio*

EXPERIMENTAL work carried on the past three years with orchids at Ohio State University has indicated that manipulation of the available nutrient supply, and variation of light intensity, of temperature and of humidity produce significant variations in flower production. These indications of the value of nutrient culture and of controlled environmental factors in orchid culture created a need for definite information as to the time of flower initiation. Such knowledge would be a basis for further experimentation to determine the proper time of, and the degree of, manipulation of the critical factors to insure maximum flower production. Research was carried on the past year in an attempt to determine the period of flower initiation in a commercially important species of orchid.

The plant used in this study was Orchid *Cattleya pinole,* a five-generation hybrid cross. Shoots were taken in consecutive lengths from dormant buds to mature shoots. The apex of the shoot was killed, fixed and then imbedded in paraffin for sectioning. Staining was done by the safranin-fast-green method as described in *Plant Microtechnique* by Johansen. Young shoots on the plants were tagged at the time active growth began and measured at weekly intervals to determine the rate of growth.

The evidence obtained indicates that shoot initiation begins in the axil of the leaf sheath of the last formed shoot while that shoot is still dormant. There is no evidence of flower primordia until after growth has begun and the shoot has attained a length of approximately 8 centimeters. At this stage the primordium has become conic in form and small protuberances are evident on the margin. During late winter months it took an average of 4 weeks for the shoot to grow to a length of 8 centimeters. Flower differentiation occurred during the period of shoot growth from 8 centimeters to 17 centimeters in length, and took an average of 3 weeks' time.

Differentiation of flower parts occurred in quick succession. First to appear were the sepals, followed rapidly by the petals and the staminal column. Last to develop was the stigmatic area of the column. The sepals, petals, labellum and column were distinct in flower buds 2 millimeters long. At a bud length of approximately 8 millimeters the column had become differentiated into anther cap, sporogenous cells, rostellum and stigma. During the last stages of development all parts elongated rapidly. At the time of anthesis the ovules are not fully developed.

The rate of shoot growth would, no doubt, vary considerably with the season of the year and the environmental conditions of the greenhouse. However, it should prove valuable to the grower to know that the first 8 centimeters of shoot growth, roughly the first month's growth, is the critical period when the cultural treatment given will determine whether flower initiation will occur; and that the second stage of growth from 8 centimeters to 17 centimeters (3 inches to 7 inches), or roughly 3 weeks of growth, will determine within the genetic limits of the species, the flower production possible from the shoot.

The Effect of the Position of the Cut on Shoot Growth of Single Eye Cuttings of Chrysanthemums

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

THE most economical type of cutting of chrysanthemum, involving a single eye, consists of cutting the stem into sections with one bud and leaf to a section, often called "leaf bud" cuttings. During 1941 and 1942 it was recommended to commercial growers that the stem be cut above the node and in cases of long internodes a portion of the internode be cut off leaving the node and an internodal space below it of approximately ¼ to 1 inch.

One chrysanthemum grower on Long Island, New York, succeeded in rooting nearly 100 per cent of 15,000 cuttings but only about 10 per cent started top growth within a reasonable time. He cut the stem in sections having one eye each, but the cut was made close below the leaf base and the internode above was left intact rather than cutting above the node as suggested.

It was thought that the cut close to the base of the leaf might have interfered with the movement of food and other substances from the leaf and stem to the bud, thus interfering with its growth. To determine the effect of the position of the cut on the bud growth cuttings were made in each of three ways. (a) Heel bud cutting, consisting of a leaf with the bud and a shield shaped section of the stem attached to it. This shield was cut starting about ⅛ inch above the bud and ending the same distance below the petiole attachment to the stem, cutting through to the pith of the stem. (b) Single eye cutting with the cut as close to the base of the petiole as possible. The internode above the bud was left connected with it. (c) Single eye cutting with the cut above the bud within ⅛ inch and leaving the internode below the petiole attached.

Similar cuttings were treated with Hormodin No. 1 dust. The variety was Popcorn, and the cuttings were taken June 30. The top five cuttings having well developed leaves were used. The data in Table I were taken August 6.

TABLE I—EFFECTS OF POSITION OF THE CUT AND HORMODIN TREATMENT ON THE GROWTH OF THE BUD

Amount of Bud Growth (Inches)	Number of Cuttings With Various Amounts of Growth							
	Hormodin				No Hormodin			
	Heel Bud	Cut Below Bud	Cut Above Bud	Total	Heel Bud	Cut Below Bud	Cut Above Bud	Total
No growth	10	11	2	23	0	11	0	11
1	11	11	4	26	18	13	1	32
2	4	3	7	14	9	0	2	11
3	0	0	10	10	0	0	12	12
4	0	0	2	2	0	0	10	10
5	0	0	0	0	0	0	2	2
Total	25	25	25	—	24	24	27	—

It is evident that the bud grew more rapidly when the cut was made above the bud than when made below it or when heel bud cuttings were used. Hormodin treatment delayed bud growth.

Low Temperature and Desiccation as Factors in Winter Killing of Garden Roses[1]

By R. C. ALLEN and G. N. ASAI, *Cornell University, Ithaca, N. Y.*

ONE of the chief problems in growing garden roses in the colder regions of the United States is protection against winter injury. The usual practical methods recommended for protecting rose plants have in general been unreliable and at best only partially effective. To protect roses intelligently, it is necessary to know specifically from what they are to be protected. The most common causes of winter injury to woody plants are low temperatures and desiccation. In this paper, data and discussion are presented to show the effects of desiccation and low temperatures as factors in winter injury of garden roses together with observations on the relative hardiness of different tissues in the stem, ice formation within the tissues and the relative hardiness of roots and tops.

MATERIALS AND METHODS

Material from vigorous, well established plants growing in the garden was used for the study. The following varieties were selected because they were thought to represent a wide range in hardiness and are commonly grown: Radio, hybrid tea; Radiance, hybrid tea; Frau Karl Druschki, hybrid perpetual; Dorothy Perkins, Climber (*Rosa multiflora* x *R. wichuraiana*); Ames No. 6, Understock (*R. multiflora* x *R. blanda*); *Rosa multiflora*. All but Ames No. 6 and *R. multiflora* were budded plants.

Two canes of each of these varieties were taken from the garden at approximately 2-week intervals from mid-October to mid-January when they no longer were usable because they had been killed by low temperature. Both moisture and resistance to low temperatures were determined on samples of the same canes. The entire canes were cut in pieces 3 to 5 inches long. Starting from the base, every sixth piece was placed in a group to receive the same treatment. Thus group I was made up of section Nos. 1, 7, 13, 19, and so on, group II of Nos. 2, 8, 14, 20, and so on and the other groups in similar sequence. Six such groups were obtained from each cane. The number of pieces in each group varied from 3 to 10 depending upon the length of the canes. Group I was used for moisture determination, group II as a check and groups III to VI for low temperature treatments.

In making the moisture determination, the fresh weight for each piece was obtained. The material was then killed in steam (2 minutes at 100 degrees C) and placed in a vacuum oven at 140 degrees F with 25 inches of mercury vacuum for 48 hours, cooled and weighed. The per cent moisture was calculated on the dry weight basis, that is

$$\text{per cent moisture} = \frac{\text{Fresh Weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100$$

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[1] Appreciation is expressed to Dr. A. J. Heinicke, and to other members of the staff of the Department of Pomology for the use of laboratory space and refrigeration equipment used in this study.

Where it was desired to determine the amount of desiccation possible before injury occurred, canes were collected and the cut surfaces coated with paraffin. They were then placed in a 40 degrees F refrigerator to dry slowly. Samples of each variety were removed from the refrigerator at weekly intervals, cut into 3- to 5-inch sections and moisture and viability tests were made on alternate pieces. To determine viability, the alternate section was allowed to absorb water for 24 hours after which it was placed in a moist chamber at room temperature. If the buds started to grow and the cane appeared normal, it was considered viable.

In studying the effects of low temperature two types of observations were made. One was to observe the canes in the garden after each lowering of the minimum temperature had occurred. To determine the minimum temperature an official Weather Bureau minimum thermometer was placed near the plants, 2 feet above the ground and left fully exposed.

The second type of observation was made on canes subjected to different minimum temperatures in a freezing chamber. The temperatures used were 18 degrees, 10 degrees, 3 degrees, —4 degrees, —11 degrees, and —18 degrees F. The canes were cooled at the rate of 11 degrees F per hour and held at the minimum temperature for 18 hours. They were then removed from the cold chamber and allowed to thaw slowly in a 40 degrees F refrigerator. They were then placed in moisture chambers at room temperature or in moist sand to determine their viability or the extent of injury.

RESULTS

Desiccation Studies

Changes in Moisture Content:—It may be seen from Table I that no marked loss of water occurred in any of the varieties during the period from October 13 to January 7. The tests had to be discontinued at this time because all of the above ground parts of the varieties Radiance, Radio, Frau Karl Druschki and Dorothy Perkins were completely killed or badly injured. Other varieties also suffered their greatest injury at this time concurrent with a minimum temperature of —20 degrees F.

TABLE I—MOISTURE CONTENT OF ROSE CANES

Variety	Per Cent Moisture (on Dry Weight Basis—Average of Two Canes)					
	Oct 13	Oct 27	Nov 10	Nov 24	Dec 15	Jan 7
Radiance	117	117	113	108	117	104
Radio	127	122	113	104	117	100
Frau Karl Druschki	117	117	113	108	117	117
Dorothy Perkins	113	104	108	108	113	108
Ames No. 6	—	—	85	—	92	92

Canes waxed with a Dow emulsion for the purpose of preventing loss of water showed a normal moisture content but were killed when the temperature dropped to —20 degrees F.

It was noted that after canes were killed, presumably as the result of low temperature, they lost water rapidly, while as shown by Table I changes in the moisture content of the living canes were relatively slight.

Amount of Moisture Lost Before Injury:—An attempt was made to determine the degree of desiccation which the canes could withstand and still recover. Considerable difference was noted in the rate of drying in different parts of the cane. The tips dried more rapidly and consequently lost a greater percentage of water in a given time than the base. As a result, the portions near the tips reached the critical moisture content and were killed before the basal portions were injured,

In order to arrive at the approximate amount of moisture rose canes could lose before being killed, the moisture percentage of the section having the lowest water content and still living was averaged with the moisture percentage of the dead section showing the highest water content. In the case of Dorothy Perkins the mean of these averages based on 14 canes was 47.7 ± 2.4 per cent. This would indicate that when the moisture content is 50.1 per cent or above, the cane is not likely to be seriously injured, while if the moisture content is below 45.3 per cent it is more than likely dead. Approximately the same range was observed for Radiance. Since the normal moisture content of Dorothy Perkins was 113 per cent on the dry weight basis, 50 per cent or more of its original content could be lost without injury.

It was observed that canes killed by desiccation were always badly shriveled and turned a dull gray green color. This was quite distinct from the brown color observed when canes were killed by other means.

LOW TEMPERATURE STUDIES

In the Garden:—In so far as possible, observations were made on especially selected plants growing in the garden. No injury was noted on the varieties involved until weather in which the minimum temperature dropped to around 0 degree F was experienced. Such temperatures are normally expected in the vicinity of Ithaca during December, January and February. In the course of these observations during the winter of 1941–42 low temperatures occurred on December 8 (4 degrees F), December 12 (—1 degree F) and January 7 (—20 degrees F). Table II gives the minimum temperatures reached and the tissues injured for the varieties studied.

While the pith and inner xylem of Radiance and Radio were killed at —1 degree F throughout the length of the canes, plants transplanted to the greenhouse made normal growth demonstrating that such injury was not sufficient to noticeably affect subsequent growth.

In the case of Dorothy Perkins the upper half of the canes was completely killed at —20 degrees F. Since the pith, xylem rays, inner cortex and pericycle were seriously injured, the plants made only an abnormal stunted growth when transplanted to the greenhouse. The pith injury in Ames No. 6 and Rosa multiflora did not prevent the plants from growing normally.

Artificial Low Temperature Treatments:—Samples of the test varieties were subjected to different degrees of low temperature at intervals

TABLE II—INJURY OBSERVED ON ROSE CANES IN THE GARDEN AT PROGRESSIVELY LOWER TEMPERATURES

Variety	Minimum Temperature (Degrees F)	Tissues Killed
Radio	4	None
	−1	Pith, inner xylem
	−20	All canes killed
Radiance	4	None
	−1	Pith, inner xylem
	−20	All canes killed
Frau Karl Druschki	4	None
	−1	Pith and inner xylem of upper portion of canes
	−20	All canes killed
Dorothy Perkins	4	None
	−1	None
	−20	Upper half killed. In the lower half pith, xylem rays, inner cortex and pericycle seriously injured
Ames No. 6	4	None
	−1	None
	−20	Pith
Rosa multiflora	4	None
	−1	None
	−20	Pith

beginning about the middle of October. Considerable variation in the resistance to low temperatures was noted as the season progressed and between varieties. Since the minimum temperatures in the freezing units were maintained at 7 to 8 degree intervals, the exact killing temperature was not determined. In Table III is recorded the minimum temperature at which the canes were killed. Between this and the interval above lies the critical killing temperature.

TABLE III—MINIMUM TEMPERATURE AT WHICH ROSE CANES WERE KILLED IN FREEZING CHAMBERS ON DIFFERENT DATES

Variety	Oct 12 (Degrees F)	Oct 27 (Degrees F)	Nov 10 (Degrees F)	Nov 24 (Degrees F)	Dec 15 (Degrees F)	Jan 14 (Degrees F)
Radiance	21	3	3	3	−4	—
Radio	21	3	3	3	−4	—
Frau Karl Druschki	18	−4	−4	−4	−4	—
Dorothy Perkins	18	−4	−4	−4	−12	−12
Ames No. 6	—	—	−18	−18	−18	−18

It is to be noted that on October 13th all of the varieties were killed at higher temperatures than later in the season. The weather prior to this date had been comparatively mild. The following two weeks were cold and by October 27th considerably lower temperatures were necessary to cause injury. The data indicate that cold resistance developed rapidly during this period and while hardiness did increase after this date, the rate was much less rapid.

It should also be noted that the varieties Dorothy Perkins and Ames No. 6 were killed in the cold chamber at —12 degrees F and —18 degrees F, but were only slightly injured in the garden when the minimum temperature was —20 degrees F (Table II). This may have been due to a more rapid rate of cooling and a longer exposure at the minimum temperature in the cold chamber. However, observation on material from the garden and from artificial low temperature treatments showed a definite relationship between the amount of injury and the minimum temperature reached, other factors being equal.

Canes which were completely killed appeared water soaked immediately upon thawing. Later, if left at temperatures above freezing they developed a dark brown color.

Relative Hardiness of the Different Tissues:—Observations on material from both the garden and cold chambers showed that the different tissues of the stem varied in their resistance to low temperatures. Microscopic examination of stems subjected to low temperatures during mid-October before much cold resistance had developed, showed that the pericycle and the phloem rays were the first to be injured. The inner cortex, phloem, cambium, outer cortex, xylem rays and pith were next in order.

By late October after considerable hardening had occurred, the pith and the xylem rays were the first to be killed. The other tissues, however, remained in their same relative order of resistance. It appeared that the pith and xylem rays were the most resistant tissues when the plant was in the non-hardened state. These tissues did not seem to develop hardiness to the extent of the other tissues and in this and later periods were relatively less resistant.

Since the outer cortex was always the last to be injured in the hardened canes, stems often appeared uninjured upon superficial examination even though the inner tissues were completely killed. It was noted that even in the outer cortex sometimes patches of cells would be killed and later turn brown while most of the tissue remained green. The buds were killed before the outer cortex, but were more resistant than the inner cortex.

It was observed that very often in the early spring canes would appear to be green and healthy, but the buds would fail entirely to develop or to grow for only a short time. Microscopic examination showed that in such cases, at least the pith and xylem rays were killed and usually the inner cortex, phloem and cambium were also injured.

Ice Formation in Stems:—Material of the different varieties was obtained from the garden, immediately after exposure to —20 degrees F, sections were mounted in mineral oil, studied under the microscope and photographed. The same procedure was carried out for material treated in the cold chambers.

Large ice masses were observed in the tissues of all the varieties. They varied in size and in general were lenticular in cross section. The individual cells were distorted in all cases but the degree of distortion was much greater in Radiance, Radio and Frau Karl Druschki than in Ames No. 6. In Dorothy Perkins it was more or less intermediate.

Fig. 1 shows photomicrographs of the normal cell arrangement prior to freezing, the appearance while frozen at —20 degrees F and the condition of the tissues a day or two after thawing for the varieties Radiance and Ames No. 6. In the sections photographed while frozen the large masses of ice can be seen to occupy a large proportion of the space outside the cambium. In both varieties, the normal cell arrangement was so distorted that the individual cells in certain areas were indistinguishable. After thawing, the tissues returned to approximately their normal position. The darkened areas in the photomicrograph of Radiance after thawing (Fig. 1, C) indicated injury which was most prominent in the pericycle, inner cortex, phloem, cambium and xylem rays. No injury from which the stems were unable to recover was discernible in Ames No. 6.

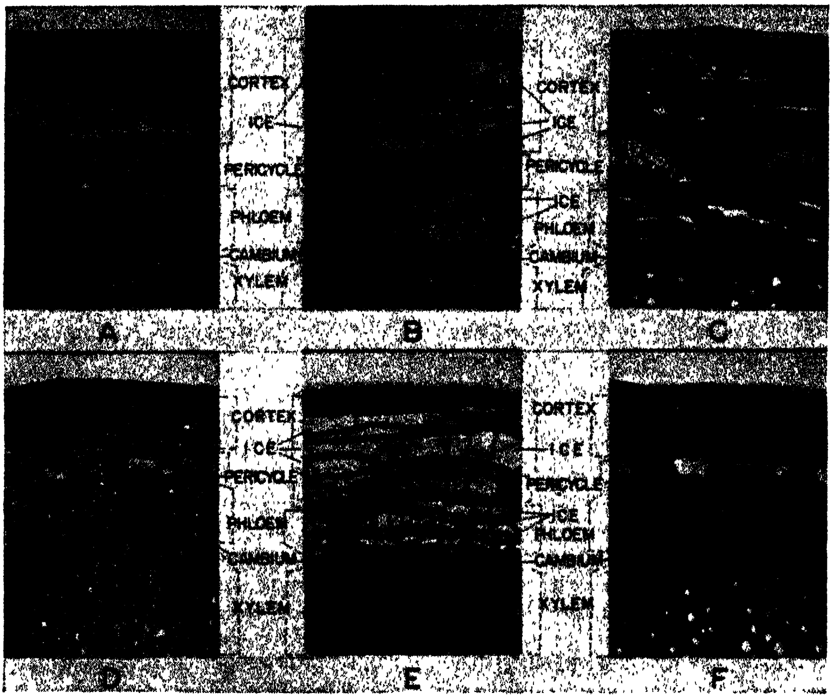

FIG. 1. Ice formation in stems of roses frozen at —20 Degrees F. Cross section photomicrographs showing a section of the stems. A, Radiance before freezing. B, Radiance frozen at —20 degrees F. C, Radiance after thawing. D, Ames No. 6 before freezing. E, Ames No. 6 frozen at —20 degrees F. F, Ames No. 6 after thawing. The darkened areas in C indicate dead tissue. (Magnification 75 X.)

In Radiance cleavages in the tissues were often noted after thawing indicating another effect of the extreme distortion during the frozen condition. It was also noted that the cells were somewhat smaller in size in the more resistant varieties than in the tenderer ones.

Numerous observations on stems frozen at varying minimum temperatures showed that ice crystals began to form in the intercellular spaces at temperatures slightly below 32 degrees F. As the temperature was lowered they increased in size as water was withdrawn from the cells of adjacent tissues.

Relative Hardiness of Roots and Tops:—Plants of the relatively hardy Ames No. 6 that had been propagated by cuttings were dug in late February. The entire plants were placed in the cold chambers. One group of four plants was cooled to 3 degrees F while the other was cooled to —4 degrees F, and held at these temperatures for 2 hours. No injury occurred in the tops at either temperature. At 3 degrees F the roots were uninjured, while at —4 degrees F they were completely killed. This would indicate that roots of this variety were killed at approximately 0 degree F to —1 degree F, since the temperature interval between the treatments was 7 degrees F. Since the canes in previous experiments had not been killed until a minimum temperature of —18 degrees F (Table III) had been reached, the differential in hardiness between roots and tops appeared to be approximately 14 degrees F.

It was impossible to determine the relative hardiness of roots and tops of the other varieties because they had been budded on *Rosa multiflora* understock. However, since *R. multiflora,* from observations in the garden (Table II), appeared to be comparable as far as the hardiness of the tops was concerned with Ames No. 6, it seemed reasonable to expect the same degree of root hardiness in *R. multiflora* as in Ames No. 6. Therefore, if the roots of *R. multiflora* would withstand temperatures of 0 degree F they possess about the same degree of cold resistance as the tops of the varieties tested with the exception of Dorothy Perkins, where there would be a differential of 8 degrees F.

DISCUSSION

The observations and data here reported indicate that in the Ithaca, New York region, desiccation is not an important factor in winter injury. Moore (3) found that rose plants that were waxed in the fall were less injured than those that were not waxed. Since his measurement of injury was based upon the subsequent growth during the following summer, and since no direct observations were made to determine the extent of desiccation between the two treatments, the evidence is not strong.

Emerson as quoted by Chandler (2, page 617), Brierley (1) and others have shown that in the middle west desiccation is the chief cause of winter injury in red raspberries. Drying out of the raspberry canes occurred when the soil was deeply frozen, the sun bright and high winds prevailed. Injury was prevented by coating the canes with paraffin. However, raspberries are apparently more resistant to low temperatures than are roses since Chandler (2, page 617) states that at Ithaca, New York following the severe winter of 1917–18 that injured severely nearly all other fruits, red raspberry canes showed little injury. During the winter of 1917–18 a minimum temperature of —26 degrees F was recorded in the region.

In the vicinity of Ithaca, New York the conditions of deeply frozen soil, bright sunlight and strong drying winds do not normally occur until very late in the winter or very early spring. This is after the period of low temperatures has passed. Since the data presented demonstrate that rose canes are killed by minimum temperatures commonly experienced in the region, it seems highly probable that injury occurred during periods of low temperature and the canes were already dead when conditions favorable for desiccation arrived. Once the canes were killed they lost water readily and would have done so even if the conditions for drying out were not severe.

Much of the evidence for desiccation as a factor in winter injury is based upon the observation that frequently rose canes appear normal in the spring, but the buds fail to develop normally or grow for only a short time before withering. This response is usually attributed to periods of hot drying winds just prior to the time the buds start growth. The observations have never indicated the light gray green, shrivelled characteristics common to rose stems dried under controlled conditions. Chandler (2, p. 617), states that there is some evidence that when red raspberry canes die without browning it is not direct freezing to death but drying to death. Furthermore, no examination of the internal tissues has been recorded in connection with such observations.

As has been pointed out in this paper, the outer cortex is the most resistant of the tissues to low temperatures. Because of this, rose stems may appear healthy from the outside, while the inner tissues may be seriously injured. Observations of material where the buds or shoots failed to develop normally, showed this to be the case. Furthermore, the data showed that rose canes may lose 50 per cent or more of their normal moisture content without danger of serious injury.

The problem of winter protection, at least in this locality, thus appears to be one of keeping the canes above the critical minimum temperature. Reliable practical methods for doing this need to be developed and further study of this phase of the problem is underway at the Cornell Test Gardens. Since there is evidence that rose stems develop cold resistance through the late fall months, a study of this phase is being undertaken to determine the conditions producing the greatest degree of resistance. Such information would serve as a basis for an indirect approach to the winter protection problem.

SUMMARY

Canes of the rose varieties Radiance, Frau Karl Druschki, Dorothy Perkins, and Ames No. 6 in the garden showed no marked loss of water during the period of October 13, 1941 to January 7, 1942. Determinations showed that the moisture content of canes of Dorothy Perkins could be reduced to 47.7 ± 2.4 per cent without serious danger of injury. Rose canes killed by desiccation were always light gray green in color and appear badly shrivelled.

A minimum temperature of —1 degree F produced slight injury to canes of Radio, Radiance and Frau Karl Druschki in the garden. A minimum temperature of —20 degrees F produced complete killing in these varieties but only slight injury occurred in Ames No. 6 and *Rosa multiflora*. All varieties killed at a much higher temperature in the early fall than later in the season. In the observations recorded, cold resistance increased most rapidly during the period of October 13th to 27th. Thereafter more resistance to cold developed but at a slower rate.

Canes completely killed by low temperatures appeared water soaked immediately upon thawing but later the tissue turned brown. The pericycle and phloem rays were the first tissues to be killed in non-hardened rose canes. The inner cortex, phloem, cambium and outer cortex, xylem rays and pith were next in order to be injured. After hardening the pith and inner xylem were the first to be injured while the outer cortex was the most resistant. Large ice masses greatly distorting the tissues were observed in stems frozen at low temperatures. It was noted that the ice crystals began to form in the intercellular spaces and gradually increased in size as the temperature was lowered withdrawing water from the surrounding tissues.

In the variety Ames No. 6 the tops were able to withstand temperatures about 14 degrees F lower than the roots.

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Retardation of Shoot Development on Roses During Common Storage by Treatment With Growth-Regulating Substance

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ROSE BUSHES are often troublesome to store. The plants apparently have a very brief dormancy requirement and develop shoots in storage much more readily than other nursery stock. The discovery in recent years of the bud-inhibiting effects of synthetic growth-regulating substances suggested that these compounds might be of aid in preventing shoot development on roses while in storage.

Storage tests with growth-regulating-substance-treated rose bushes have yielded very promising results in two storage seasons (2). Briefly, it was found that spray applications containing either a-naphthylmethylacetate or a-naphthylethylacetate at a concentration of from 0.01 to 0.005 per cent in a dilute (¼ to ½ per cent) wax-emulsion carrier applied to dormant plants of the Ami Quinard variety of rose prevented shoot growth on stored plants until late April. Likewise, vapor treatments with these compounds applied to similar plants at the rate of 0.3 to 0.5 grams per 1000 cubic feet for 16 hours at 70 degrees F gave beneficial effects; not only was the dormant period of the treated plants prolonged while in storage, but also more root and shoot growth and more flowers per plant were produced by the treated than by the untreated plants when both were field-planted at a rather late date.

This report is concerned with experiments that were designed to give information relative to factors that might affect the degree of response from growth-regulating-substance treatment to prolong dormancy, or from a practical standpoint to answer the following questions: (a) What effect does plant maturity have on the response to treatment; (b) do all varieties of rose respond alike to treatment; and (c) what effect will the treatment have on plant species other than rose that either receive the same treatment or are stored in the same room with treated rose bushes.

EFFECT OF PLANT MATURITY ON RESPONSE TO TREATMENT

Even under unusually favorable conditions for growing roses in the field a few at least are dug and stored in an apparently immature condition. In years of unfavorable weather at the time of digging a high percentage of such plants are frequently stored. These bushes constitute material that is readily infected with molds and "die back" (3) in storage. It seemed possible that growth-regulating-substance treatment might be of especial aid in handling these plants, either by conserving the limited stored food materials in them or by preventing shoot growth that becomes a favorable medium for mold growth which upon further development will attack the more mature plants.

Two lots of 40 plants each of 1-year-old field-grown Ami Quinard rose bushes were selected out of a shipment of 1000 bushes. In one lot the plants so selected were definitely less mature at the time of digging than in the other, as was indicated by the presence of many succulent canes having green leaves still attached. Upon examination by the IKI test it was found that the immature plants were very low in relative starch content, whereas the mature plants had an abundance of stored starch. The two lots were also selected so that the individual plants of each were of approximately the same size and weight.

Twenty plants each from the mature and the immature lots received a vapor treatment on January 6 of 0.3 grams of a-naphthylmethylacetate per 1000 cubic feet for 16 hours at 70 degrees F, while the remaining 20 plants were left untreated for controls. The resulting four lots were then placed in common storage. At intervals throughout the storage period records were taken on an individual plant basis of the accumulative number of shoots produced, as well as the percentage cane loss per plant, based on the total cane length and the amount destroyed by molds or other agents.

The results are presented in Table I. It is apparent that the growth-substance treatment to plants of high starch content (mature plants) resulted in a very marked reduction in shoot growth and in cane loss throughout the storage period in comparison with high-starch untreated controls. It should be noted here, that although broken and weak canes were removed from all plants in the test, the remainder of the canes were not cut back. Normally, some topping is given to the bushes before storage. The presence of these slightly immature tops may have tended to accentuate the differences somewhat, since the figures for percentage dead canes at the April 16 and May 2 dates appear somewhat high (35.2 per cent and 39.7 per cent, respectively) in the control lot.

TABLE I—SHOOT GROWTH AND CANE LOSS ON MATURE AND IMMATURE AMI QUINARD ROSES HELD IN COMMON STORAGE WITH AND WITHOUT TREATMENT TO PROLONG DORMANCY (TREATED AND STORED JANUARY 6, 1941)

Date	Mature Plants With High Starch Content				Immature Plants With Low Starch Content			
	Control		Treated*		Control		Treated*	
	Mean No. of Shoots	Per Cent Dead Canes	Mean No. of Shoots	Per Cent Dead Canes	Mean No. of Shoots	Per Cent Dead Canes	Mean No. of Shoots	Per Cent Dead Canes
Jan 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan 15	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0
Feb 1	0.0	0.0	0.0	0.0	1.6	14.6	0.0	8.4
Feb 16	1.3	1.5	0.0	0.0	2.7	16.2	0.0	10.5
Mar 3	2.5	4.5	0.0	0.0	3.5	25.5	0.0	22.6
Mar 17	6.4	18.8	0.0	1.3	14.2	29.8	0.5	39.7
Apr 1	12.3	28.6	0.0	2.4	20.8	32.5	13.4	52.5
Apr 16	18.4	35.2	1.5	4.7	32.6	43.5	15.8	60.6
May 2	26.5	39.7	3.8	6.2	46.4	58.4	17.3	73.7

*Treatment = 0.3 grams a-naphthylmethylacetate per 1000 cubic feet, for 16 hours at 70 degrees F.

Comparison of the growth-substance-treated and control plants of low starch content shows that in the early stages of the storage period the treatment was effective in controlling shoot growth and reducing cane loss. However, the effective period was at least a month shorter in duration than with plants of high starch content. Not only did the treated low-starch plants begin to break buds by March 17, 2 weeks before shoots appeared on treated high-starch plants, but they also appeared to be in a very rapid state of decline as evidenced by a significantly greater cane loss than the comparable control plants after that date. By May 2, these plants had lost almost three-quarters of their total cane length. It would appear from these results that under common storage conditions it would be hazardous to hold immature plants over a very long period, even though treatment with growth-regulating substance may reduce shoot growth and the plants may appear to be in excellent condition early in the storage period.

The data on "number of shoots" for the two control lots show that the low-starch controls produced a greater number of shoots than did the high-starch controls, especially in the last three record periods. In this connection, it should be mentioned that the two lots were more nearly alike when compared on the basis of "total length of shoots produced". The high-starch controls appeared to possess stronger apical dominance. These plants produced a few shoots which were very strong growers, whereas in the low-starch controls the plants produced a large number of weak, spindly shoots distributed farther downward from the apex of the canes.

The plants were set in the field on May 2 for further observation. Notes taken on June 7 were as follows for each lot: High-starch, control, 17 living, all weak; high-starch, treated, 20 living, 15 vigorous, 5 weak; low-starch, control, 5 living, all very weak; low-starch, treated, 2 living, both very weak.

Rose Varietal Response to Treatment

In order to determine whether or not rose varieties differ widely in their response to chemical treatment to prolong the dormant period in storage, the 15 varieties listed in Table II were selected for such a test. Included were those that start vegetative growth quickly, as well as those that are slower in breaking dormancy when held in common storage.

The varieties selected were given a vapor treatment at room temperature (70 degrees F) for 16 hours with a-naphthylmethylacetate at three concentrations, *viz.,* 0.1 gram, 0.3 gram, and 0.5 gram per 1000 cubic feet.

The bushes used were 1-year-old Eastern field-grown and the individual plants of each variety were selected for uniformity and pruned to approximately the same total cane length per plant. Twenty plants were used in each concentration of growth-regulating substance tested, and 20 plants were included as untreated controls so that a total of 80 plants of each variety were used.

The treatments were applied on March 2, and the plants held for 60 days in common storage. At the end of this time the control plants in all varieties (Fig. 1) and certain of the treated lots were showing considerable shoot growth. After recording the number and length of etiolated shoots that had grown out in storage the shoots were removed and the plants transferred to a 65 to 70 degrees F greenhouse for forcing. Although the plants in some variety lots had started active growth sooner than others, at the end of 9 days in the greenhouse all had started, and on the 14th day when growth was well advanced a record was made of the number and length of new shoots that had been produced.

A summary of the results is shown in Table II. Although data on the length of shoots are not included in the table in all cases, these data were of the same relative magnitude as the bud-count data.

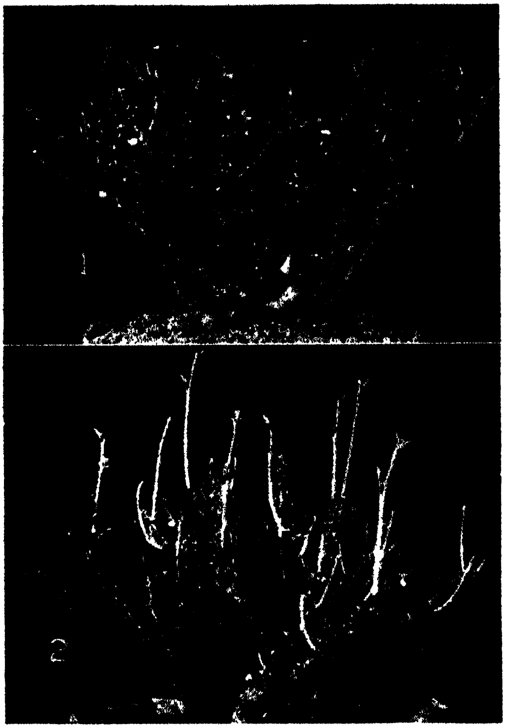

FIG. 1. Edith Nellie Perkins variety of rose after 60 days in common storage. 1, Contro.l 2, Treated. Treatment was with the vapor of a-naphthylmethylacetate applied on March 2 at the rate of 0.3 gram per 1000 cubic feet for 16 hours at 70 degrees F. Photograph taken, May 1.

It is apparent that the varieties did not respond alike in all cases to a particular treatment given to prolong the dormant period while in storage. The varieties Chatillon, Topaz and Poulsen's Yellow were the most difficult ones to keep in a dormant condition by treatment. They are also varieties that tend to start growth earlier under commercial common storage conditions.

Treatment with 0.1 gram a-naphthylmethylacetate tended to cause more buds to break than on the untreated control plants in all varieties but one of the 15 under test. Statistical analysis of the data shows that in the case of six varieties this increase in bud break was significant (5 per cent level) and with four varieties this effect was highly significant (1 per cent level). It would appear from these results that this low concentration of growth-regulating substance when applied to rose plants tends to break dormancy or stimulate more shoots to elongate in common air storage than develop on similar plants not receiving such treatment. This effect was also obtained with several other chemicals applied to the Ami Quinard variety of rose in low concentration.

Comparison of the 0.3 gram and the 0.5 gram per 1000 cubic feet treatments with a-naphthylmethylacetate shows that the former concentration is to be preferred; not only was it effective in prolonging the dormancy but it did not cause the noticeable cane injury found on six of the varieties following treatment with the stronger of these two concentrations (Table II).

Under greenhouse forcing conditions hybrid tea rose plants are grown largely for cut flower production. Stem length and flower size are of prime importance. For this reason, three or four vigorous shoots per cane are more desirable than a larger number of weaker shoots.

TABLE II—SHOOT DEVELOPMENT IN COMMON STORAGE OF FIFTEEN VARIETIES OF ROSE BUSHES SIXTY DAYS AFTER TREATMENT WITH GROWTH SUBSTANCE, ALSO SUBSEQUENT SHOOT DEVELOPMENT ON THE SAME PLANTS AFTER FOURTEEN DAYS IN A 60 TO 65 DEGREES F GREENHOUSE (TREATED MARCH 2, 1941, RECORD TAKEN MAY 1, 1941)

Variety	Mean Number of Shoots Grown Out Per Plant in Common Storage*				Mean Number of Shoots Per Plant on the Same Plants After 14 Days in Greenhouse			
	Control Plants	Concentration of a-Naphthylmethylacetate per 1000 Cu Ft (16 Hrs, 70 Degrees F)			Control Plants	Previous Treatment a-Naphthylmethylacetate per 1000 Cu Ft		
		.1 Gram	.3 Gram	.5 Gram		.1 Gram	.3 Gram	.5 Gram
Ami Quinard	15.65	30.10	0.00	0.00	4.00	3.90	12.00	10.50
Chatillon	66.45	128.05	65.40	11.70	22.05	20.50	45.10	32.85
Duquesa de Penaranda	7.80	4.60	0.00	0.20†	4.60	5.95	10.00	12.15
Editor McFarland	19.90	40.05	0.00	0.00	2.00	3.10	14.65	12.10
Edith Nellie Perkins	5.60	15.30	0.00	0.00	4.55	2.60	11.10	13.25
Etiole de Hollande	12.05	28.90	0.50	0.00	2.40	4.15	15.15	18.65
Girona	5.80	11.20	0.60	0.00†	4.60	3.85	19.10	17.50
Golden Dawn	20.05	26.70	0.00	0.00†	2.75	4.00	15.05	11.95
Guinee	3.90	4.05	0.00	0.00	4.50	2.35	6.90	8.65
Margaret McGredy	14.20	11.60	0.70	0.00	2.65	4.10	16.15	12.05
Poulsen's Yellow	26.45	32.05	10.00	0.00†	11.00	12.90	18.15	16.70
Radiance	6.75	12.00	0.00	0.00	5.20	2.85	11.45	13.05
Radio	9.50	14.85	0.00	0.00†	4.35	3.05	14.40	12.10
Ramon Bach	14.45	20.05	0.00	0.00	2.05	4.10	16.70	10.40
Topaz	20.15	36.00	0.50	0.00†	5.10	2.95	16.85	14.55

Difference necessary for significance at 5 per cent level, 6.95 at 5 per cent level, 10.75
at 1 per cent level, 10.01 at 1 per cent level, 14.35

*20 plants of each variety used per treatment.

†Moderate injury from treatment.

All the hybrid tea roses in this variety-response study were pruned to four to six canes, and it would seem, therefore, that individual plants producing a total of eight to 12 shoots, would be considered suitable for flower production. The variety Chatillon, a polyantha type, would more likely be grown as a potted plant and the consideration here would be for the production of plants with many shoots to produce an abundance of flowers for a massed color effect.

The data in Table II show that upon removal to the greenhouse the control plants were markedly inferior in shoot production to those given either the 0.3 gram or the 0.5 gram treatment of a-naphthylmethylacetate. In all 15 varieties this difference between controls and treated plants is highly significant. Treatment with 0.1 gram of this chemical resulted in no significant increase in shoot production.

EFFECT OF TREATMENT ON MISCELLANEOUS NURSERY STOCK

Nurserymen often place plants of species widely different in character in the same common storage with rose bushes. It seemed desirable to know what effects these growth substances would have on such plants, and whether it would be necessary to remove them when treating with vapors to prolong the dormant period of roses.

On March 27, 1940, an experiment was set up to obtain information on this point. The plants were so arranged as to give information relative to the effectiveness of treatment at different distances between the plants and the vapor source during the treatment period.

The plants used are listed in Table III. For the most part, they were selected as being representative of 1-year fruit trees of apple, peach, pear and cherry that are commonly stored, as well as several types of deciduous ornamental plants that may be held for brief periods in common storage houses. All plants were dormant when the experiment was set up on March 27 and, for comparative purposes, plants of the Guinee rose were included in the experiment. Conditions were representative of those encountered when plants are held by the nurseryman for late shipment, or as in the case with apple root grafts, when seasonal conditions prevent earlier planting in the field.

In treating with vapor, a tight common storage room of 28,000 cubic feet capacity was used. A-naphthylmethylacetate at the rate of 0.5 gram per 1000 cubic feet was volatilized for 16 hours. For comparative purposes a set of plants was sprayed with an oil-emulsion spray containing ¼ per cent light machine oil and 0.01 per cent of the same chemical. The sprayed lot and a control lot were removed from the storage during the period of treatment.

The growth substance was volatilized on a hot plate placed at one end of the room. Sets of the plants listed in Table II had been grouped on the floor at distances of 4, 8, 12 and 16 feet from the gas source. A large ventilating fan 20 inches in diameter provided a brisk circulation of air over the hot plate in the direction of the plants throughout the treatment period.

The extent of vegetative growth found on the plants after common storage for 35 days is shown in Table III. The control plants showed considerable growth of vegetative buds during the period, many having produced shoots 4 to 10 inches in length. It is of interest that both spray and gaseous application of growth substance were about equal in effectiveness in inhibiting vegetative buds on the wide variety of plants used.

The data show that the volatilized growth substance had apparently condensed on surfaces nearest its source, even though it had been volatilized into a rapidly-moving stream of air provided by the large fan that was used. Effective inhibition of buds was obtained with plants placed 4 feet distant from the gas source; and the slightly greater number of shoots produced on the plants at 8 feet was not significantly more than those set at 4 feet. However, at a distance of 12 feet the effectiveness of the growth substance on bud inhibition was unquestionably reduced, while plants placed at a distance of 16 feet from the gas source during the treatment period were very similar to the untreated

TABLE III—MEAN NUMBER OF SHOOTS GROWING ON SEVERAL PLANT SPECIES HELD IN COMMON STORAGE FOLLOWING TREATMENT WITH GROWTH SUBSTANCES* IN OIL-EMULSION SPRAYS AND AS VOLATILIZED GAS, ALSO EFFECT OF PLACING PLANTS AT DIFFERENT DISTANCES FROM THE GAS SOURCE DURING THE TREATMENT INTERVAL (TREATED MARCH 27, 1940, RECORD MAY 1, 1940)

Species	Variety Common Name	No. Plants Per Treatment	Treatment						Remarks
			Control Shoots	Spray† Shoots	Volatilized Gas‡				
					4 ft.§ Shoots	8 ft.§ Shoots	12 ft.§ Shoots	16 ft.§ Shoots	
Acer palmatum	Japanese maple	10	22.7	5.4	2.4	5.0	14.7	20.5	No apparent injury
Amygdalus persica	Peach seedlings	10	29.1	0.0	0.0	0.8	16.5	22.6	Severe injury in sprayed lots
Amygdalus persica	Peach, Elberta 1-year-tree	10	13.4	0.0	0.0	0.3	8.8	10.1	Severe injury in sprayed lots
Diosyros virginiana	Native persimmon 1-year seedlings	10	3.2	0.0	0.0	0.0	0.2	2.6	No apparent injury
Philadelphus grandiflorus	Mockorange	10	10.5	0.0	0.2	1.9	5.3	8.5	No apparent injury
Prunus cerasus	Montmorency cherry	10	12.8	2.4	0.5	4.2	6.6	10.5	Slight injury in sprayed lots
Prunus serrulata	Japanese flowering cherry	10	32.4	0.0	0.0	2.2	12.7	26.6	Roots formed on stem of sprayed lots
Pyrus communis	Pear, Bartlett 1-year trees	10	5.6	0.0	0.0	0.0	1.9	4.6	No apparent injury
Malus sylvestris	Apple, Northern Spy 1-year trees	10	8.7	0.0	0.0	1.4	4.7	6.8	No apparent injury
Malus sylvestris	Apple, Delicious grafts	50	2.1	0.0	0.0	0.0	0.4	1.2	No apparent injury
Rosa sp	Guinee rose variety	20	10.3	0.0	0.0	0.0	2.8	9.0	Slight injury in sprayed lots

*Growth substance = a-naphthylmethylacetate.
†Spray = 0.01 per cent growth substance in ¼ per cent oil.
‡Gas = 0.5 gram growth substance volatilized per 1000 cubic feet, 16 hours at 70 degrees F.
§Distance of the plants from the gas source.

controls in the number of shoots that subsequently developed in common storage.

The different plant species did not respond alike in all cases to a particular growth substance treatment. Complete dormancy was maintained in all the species used except *Acer palmatum*, *Philadelphus grandiflorus* and Montmorency cherry; these species showed a few vegetative buds, but in all instances the number per plant was much less than in the control.

Injury from either the oil or the growth substance was severe in the sprayed lots of peach (both seedling and Elberta) and Montmorency cherry. Since the gas-treated lots did not show the injury, it is possible that injury was either caused by the oil or oil had contributed in some way to make the dosage of growth substance too strong for these plants. The plants of *Prunus serrulata*, perhaps as a result of penetration of growth-regulating substance in oil, showed swellings and root development throughout the entire stem portion of sprayed plants. This response in root production was also noted in certain lots of treated rose bushes. The possibility of using this method of pretreating prior to taking dormant stem cuttings of roses and other plants as an aid in rooting such cuttings is suggested.

Subsequent to storage, the treated plants were lined out in the field. Seasonal conditions were very favorable for transplanting even at this late date (May 2). All the plants lived, with the exception of the spray-injured lots of peach and the control lots of Delicious apple root grafts. With effective growth-regulating-substance treatments dormancy was maintained approximately a week longer, after transplanting, than in comparable control lots of each species. This initial delay in top growth may be of benefit in a dry season unfavorable for transplanting of nursery stock, since it would allow a period for root development to take place before the top began to draw on soil moisture.

The Delicious apple root grafts illustrated in Fig. 2 were the only material to show a pronounced benefit from growth substance in percentage survival. The percentages of grafts that lived of the 50 planted in each lot were as follows: Control, 74 per cent; sprayed, 80 per cent; gassed, 100 per cent. At the end of the growing season, no significant difference was found in the amount of top growth that the grafts in each lot had made. Scion rooting had not taken place in the first year, as reported by Jones (1) for growth substance applied in lanolin emulsion to grafts of the Virginia crab variety.

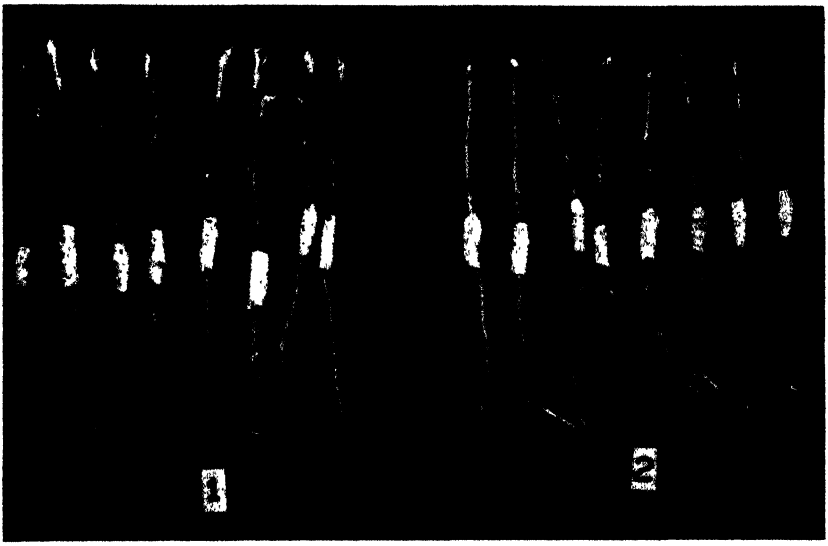

FIG. 2. Delicious apple grafts at the time of field planting on May 2. 1, Control. 2, Treated. Treatment was with the vapor of a-naphthylmethylacetate at the rate of 0.3 gram per 1000 cubic feet for 16 hours at 70 degrees F, applied on March 27. Both lots held in common storage. Photograph on May 1.

The increase in stand of grafts appeared to be due to a speeding up of callus proliferation, causing a better union between stock and scion pieces of the treated grafts. Suppression of top growth by growth-substance treatment would also reduce transpiration until the newly formed union is better able to permit passage of water to the top.

CONCLUSIONS

Treatment of rose bushes with a-naphthylmethylacetate growth-regulating substance to prolong the dormant period in common storage is most effective when applied to plants that are fully mature when stored. Although shoot growth was inhibited on immature plants, the effective period after treatment was of shorter duration and the plants were more susceptible to injury as a result of treatment than were the more mature plants of the same variety.

Rose varieties do not respond equally well in all cases to treatment with this growth-regulating substance. However, some reduction in shoot growth may be expected from most varieties. Varieties that are normally most difficult to store appear to be somewhat more difficult to inhibit with the growth-regulating substance treatment.

Because of the nursery practice of placing a number of plant species in the same storage room with roses, it is of interest that the vegetative buds of apple, pear, peach, cherry, mockorange, Japanese maple and native persimmon were also inhibited by treatments effective on roses.

Under the conditions of these experiments the vapor of a-naphthylmethylacetate appears to condense rather quickly even in a rapidly moving stream of air. For best results, therefore, in treating plants by the vapor method, the plants should be placed fairly close to the vapor source. Application at the rate of 0.3 grams of gaseous growth-regulating substance per 1000 cubic feet with exposure for 16 hours at 70 degrees F gave excellent control of shoot growth in subsequent storage.

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The Effect of Various Nitrate Levels on the Growth and Production of Greenhouse Roses

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THE use of rapid soil tests as an aid in growing greenhouse roses is becoming increasingly widespread. Many growers are using the results of soil analyses to determine the time and amount of application of nitrogen fertilizers; it is essential that they know the nutrient levels to maintain for the best growth and production. Weinard (1) as a result of observations of soil tests in experimental plots and in 25 commercial ranges suggested for roses a nitrogen level of 150 to 200 pounds per acre; according to the Spurway (2) system, this would be equivalent to approximately 85 to 110 parts per million of nitrate in the soil extract. Milne (3) reported the growing of roses in soil with a nitrate level of 25 to 50 parts per million. There have been, however, no reports of any well controlled studies of the nitrate requirements of roses growing in soil. Therefore, there has been a wide difference in opinion as to the nitrate levels which are most suitable. The purpose of this study was to determine the correlation between the nitrate level in the soil and the growth and production of roses. The first requirement of such a study was to devise a method for maintaining in the soil definite nitrate levels without wide fluctuations.

During the summer of 1940 the project was started by Dr. E. V. Staker of the Department of Agronomy and Dr. Kenneth Post of the Department of Floriculture at Cornell University, and was continued by the author during the 1941–42 season. Many difficulties were encountered, and the experience gained in the first season made it possible to maintain fairly definite nitrate levels during the second season.

Experimental Methods

Procedure:—A raised wooden bench, 6 inches deep, was divided into plots 3 feet square. The plots were separated by double board partitions which were made watertight with paraffin. The soil, a Dunkirk silty clay loam with an organic matter content of 5.84 per cent, had been in sod for several years and was put in the bench without further preparation. Superphosphate (20 per cent P_2O_5) at the rate of 5 pounds per hundred square feet of bench area and muriate of potash (60 per cent K_2O) at the rate of 1¼ pounds per hundred square feet were incorporated in the soil before planting.

Nine grafted plants of the variety Talisman were planted in each plot on June 15, 1940. Four replications of each treatment were distributed throughout the length of the bench.

It was arbitrarily decided to grow the plants at nitrate levels of 0, 5, 10, 25, and 50 parts per million in the soil extract because this range would include those levels in general use in commercial greenhouses. The nitrate level at the time of planting was 19 parts per million. No nitrogen was added to the soil until September 21 when the nitrate in all of the plots ranged from .6 to 3.8 parts per million; at this time the various treatments were begun. The nitrate levels were adjusted by adding calcium nitrate at 5-day intervals. Small quantities of a 10 per cent solution of calcium nitrate (analytical grade) were diluted with tap water and applied uniformly to the surface of the soil using a 1-quart sprinkling can. The quantity of calcium nitrate applied was adjusted according to the results of the most recent analyses. If the nitrate level was too high, the amount was reduced; if too low, the amount was increased.

From the soil analyses of October and November of the first season, it was evident that a definite nitrate content of the soil could not be maintained as long as there was leaching through the bottom of the bench. At this time waterproof Sisalkraft paper made into a trough-like arrangement was attached to the underside of the bench and the leachings from each plot were caught in a separate crock. At the time of watering this leachate was diluted in a 2-gallon sprinkling can and applied to the surface of the soil of the plot from which it came.

The roses were dried off by the usual commercial method in early March, 1941, cut back and then grown on until April, 1942 at which time the experiment was terminated.

Methods of Soil Analysis:—A representative soil sample was obtained twice a month by removing from each plot six cores of soil ½ inch in diameter from the top to the bottom of the bench; they were mixed to form a composite sample for that plot. These samples were air-dried, screened, and analyzed.

One teaspoonful (4.5 grams) of soil and 26 milliliters of Spurway's (2) acetic acid extracting solution were shaken in a flask for 1 minute and filtered. Nitrates were determined by the phenoldisulfonic acid method described by Snell and Snell (4) and compared with known standard solutions by means of an electrophotometer. Phosphorus, potassium, and calcium were determined by the Spurway method, except for the use of a stannous chloride solution instead of a square of tin in the phosphorus test; all were compared with known standard solutions. The results of the analyses were expressed as parts per million in the soil extract. The nitrogen was always expressed in terms of nitrate (NO_3). Soil acidity was measured potentiometrically with a glass electrode.

RESULTS

Nutrient Levels:—The average of the nitrate levels in the four plots of the various treatments from March 3, 1941 until April 15, 1942 appear graphically in Fig. 1. During the spring of 1941 the plots receiving no nitrogen contained from ½ to 2 parts per million of nitrate; this probably came from the tap water and the decomposition of organic matter in the soil. In the other treatments there was considerable fluctuation above and below the desired level during this period; it may be noted, however, that at all times the nitrate in the 50 parts per million plots was highest, in the 25 parts per million plots next highest, and in the other plots respectively lower.

At the time of change of personnel in July, several nitrogen applications were omitted, and the nitrate dropped below that desired. From August 15 throughout the remainder of the growing season the nitrate

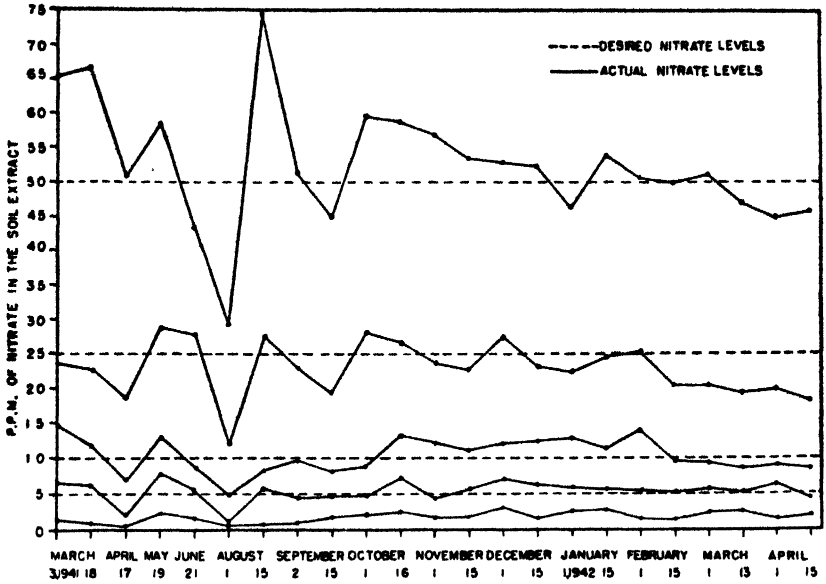

FIG. 1. Nitrate levels in the soil from March 3, 1941 to April 15, 1942.

concentrations were maintained close enough to the desired levels to be very satisfactory in this study.

Phosphorus was maintained at 5 to 10 parts per million and potassium at 20 to 30 parts per million.

Soil samples obtained September 21, 1940 ranged in pH from 4.5 to 4.7. Since a higher pH is considered better for roses, lime (calcium carbonate) at the rate of approximately 7 pounds per 100 square feet was thoroughly worked into the upper 3 inches of soil. Subsequent determinations indicated that the pH remained in the range from 5.8 to 6.2.

The calcium concentration remained at a high level (125 to 150 parts per million) in all treatments with practically no difference between treatments; often some of the low nitrate plots gave a slightly higher test for available calcium than the high nitrate plots. Therefore, it is assumed that the small amounts of calcium added at the time of nitrate application were not a factor in the differences in growth and production of the plants.

Flower Production:—The data in Table I show that the number of salable flowers and the total number of flowers increased with each increment of nitrate maintained in the soil. Flowers were considered salable if the flower and foliage showed no defects and if the stem was over 6 inches in length. In all treatments, however, less than 0.5 per cent of the total production was in the 6- to 9-inch grade. The differences in the production of salable roses were calculated to determine their mathematical significance. Because there was no significant difference between the 25 parts per million and 50 parts per million treatments, and there was a significant difference between 10 and 50 parts

TABLE I—EFFECT OF VARIOUS SOIL NITRATE LEVELS ON THE PRODUCTION OF ROSES FROM SEPTEMBER 3, 1941 TO APRIL 15, 1942

Nitrate P p m	Average Number of Flowers Produced Per Plant			Salable Flowers Expressed as Per Cent of Total	Average Stem Length (Inches)
	Unsalable	Salable	Total		
0	1.94	15.5 ±1.08*	17.4	88.9	16.4
5	2.87	25.6 ±0.28	28.5	89.9	16.6
10	2.56	29.0 ±1.05	31.6	91.9	16.7
25	2.98	30.1 ±0.93	33.1	91.0	16.9
50	2.87	33.0 ±0.64	35.9	92.0	17.1

*Probable error determined by the Bissel method.

per million treatments, there must be some point between 10 and 25 parts per million at which the significance begins. The exact point cannot be determined from this experiment.

The number of salable flowers is expressed as the per cent of total production. The data indicate that the percentage of salable flowers was generally higher in the high nitrate plots than in the low nitrate plots, but the differences are small. Similarly the average stem length of the salable flowers was nearly the same in all treatments, being slightly higher with each increase in the nitrate concentration. The keeping quality of the flowers from the various treatments was equal. The flower color was normal except in the plots receiving no nitrogen fertilizer where some of the flowers had less red color than is characteristic of the Talisman rose.

Some evidence as to the effect of the nitrate level on rose production in the various seasons is given in Table II. It is recognized that the fluctuating levels before August 15 might have had some effect on the production in September. The data show that a little more than 40 per cent of the salable flowers were cut during the fall season with little difference between treatments. The plots receiving no nitrogen had the lowest percentage in the fall season and the highest percentage of all treatments in the winter season. Whether this occurred as the result of the low nitrate or the fact that this treatment happened to crop heavily during the winter months is not known definitely. It is suspected that the latter view is correct because the 50 parts per million nitrate treatment had a higher percentage than the remaining three treatments during this period. In the spring season there were not large

TABLE II—PRODUCTION OF SALABLE FLOWERS AND AMOUNT OF CALCIUM NITRATE APPLIED BY SEASONS

Nitrate P p m	Production Expressed as Per Cent of Total Number of Salable Flowers			Production Expressed as Average Number of Flowers Per Plant Per Month			Pounds of Calcium Nitrate Per 100 Sq Ft of Bench Area Per Month		
	Sep Oct Nov	Dec Jan Feb	Mar to Apr 15th	Sep Oct Nov	Dec Jan Feb	Mar to Apr 15th	Sep Oct Nov	Dec Jan Feb	Mar to Apr 15th
0	41.6	36.0	22.4	2.15	1.86	2.31	—	—	—
5	43.3	29.6	27.1	3.69	2.53	4.61	0.54	0.36	0.22
10	44.7	27.2	28.1	4.32	2.64	5.43	0.73	0.49	0.51
25	44.3	27.4	28.3	4.44	2.74	5.69	0.93	0.57	0.70
50	44.6	30.2	25.2	4.89	3.32	5.54	1.23	0.83	1.20

differences between the various treatments except for the plots kept at the lowest nitrate levels. The percentage for the spring period was low because it included only 1½ months whereas the others included 3 months. From these data it may be assumed that with the exception of the lowest nitrate treatment, the plants at the different nitrate levels of this experiment all produced approximately the same percentage of flowers in the various seasons.

The actual number of flowers produced per plant per month in each season is also given in Table II. It may be seen that the high production periods were in the fall and spring with lower production in the winter months. In all seasons the production increased with each increment of nitrate in the soil except for the 50 parts per million treatment in the spring where the production was only slightly less than for the plot maintained at 25 parts per million.

The amount of calcium nitrate applied to the soil to maintain the proper levels is also presented in Table II. The amount of calcium nitrate required in the winter months was considerably less than in the other two seasons.

DISCUSSION

The commercial florist is interested in knowing at what nitrate levels roses may be grown in order to give the best production and quality. The results of this experiment indicate that high production was obtained when the nitrate was maintained between 50 parts per million and a point between 10 and 25 parts per million which cannot be ascertained definitely from this study. Because the 25 parts per million treatment had a level between 20 and 25 parts per million and during the majority of the season the 10 parts per million treatment was above that level, it is suspected that the minimum point is about 15 to 18 parts per million.

As there was an increase in flower production with each increment of nitrate in the soil up to 50 parts per million, the maximum nitrate level at which roses can be grown without decreasing production cannot be determined from this experiment. For this reason there is in progress an experiment with plots repeating the 10, 25, and 50 parts per million concentrations and other plots with 75 and 100 parts per million.

There was little difference in the stem length of the salable flowers in the various treatments. One may wonder why the stems were not shorter in the plots receiving no nitrogen. The plants in this treatment did not show symptoms of severe nitrogen deficiency, although the foliage was light green in color and the number of branches smaller than in the other plots. The number of flower stems was comparatively low in the plots receiving no nitrogen, but the flowers that were produced had stems which averaged almost as long as in the higher nitrate plots.

Because there was high production over such a wide range of nitrate levels, it should not be difficult for the commercial grower to maintain those levels (15 to 50 parts per million) which would be the most satisfactory. The amount of nitrogen fertilizer and the frequency of application would vary with the type of soil, kind of fertilizer, season of the year, size of plants and cultural practices such as watering, but it would not be difficult for the grower to ascertain the fertilizer applications necessary for his particular situation.

SUMMARY

By the use of a watertight bench with facilities for collecting the leachate, application of the leachate at the time of watering, application of calcium nitrate in solution every five days, and regular testing of the soil twice a month, it was possible to maintain satisfactorily uniform nitrate levels in plots of soil. This method is not recommended for commercial use but should be very helpful in studying experimentally nutrient requirements of plants in soil.

The production of salable roses and the stem length increased with each increment of nitrate in the soil. The significance of the production data is discussed. The differences between the average stem length of the various treatments were small.

The various treatments produced approximately the same percentage of salable flowers in the different seasons. As a result of the increase in production with each increment in the nitrate level, the actual number of salable flowers increased with each increment of nitrate in all seasons with the one aforementioned exception. Fewer flowers were cut in the winter than in the fall and spring months.

Less calcium nitrate was required in the winter, than in the fall and spring months to maintain a uniform nitrate level in the soil.

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The Effect of Soil Mixtures on Production and Growth of Briarcliff Roses[1]

By CONRAD B. LINK and J. R. CULVERT, *Pennsylvania State College, State College, Penn.*

THIS is a continuation of the study reported previously (1), the object of which was to observe the influence of soil media containing various amounts of organic matter on the production of flowers and vegetative growth of greenhouse grown roses.

The media used in the previous study were re-used except that half of each medium was replaced with an equal quantity by volume of coarse river sand and thoroughly mixed. The sand was added to the soil mixtures because this seemed the most expedient method of preventing the soil, Hagerstown silty clay, from cracking without changing the organic content in proportion to that of the finer soil separates in the mixture. When Hagerstown silty clay was used alone in previous studies it was found that this soil cracked badly and that the roots and root hairs were damaged. The humus was obtained from northern Pennsylvania and was dark brown to black in color and closely approached muck in character. It contained 52 per cent organic matter at the beginning of the first study and it showed little tendency to decompose during the course of the previous or the present study. The media as used in the study reported here were: one-half humus, one-half sand (by volume); one-quarter humus, one-quarter soil, one-half sand; one-eighth humus, three-eighths soil, one-half sand; one-half soil, one-half sand.

Briarcliff rose plants (grafted on Manetti) were planted in the media in raised concrete benches on May 22 and 23, 1939. They were spaced 12 by 12 inches in plots of 40 plants. Each medium was represented by four plots, randomized in the greenhouse so that each treatment occurred in each of the four benches and in similar positions in relation to the center and sides of the house.

Previous to planting, 1 pound of steamed bone meal was mixed into each plot. During the period of the study, the following total amounts of fertilizers were applied to each plot of 40 square feet: sodium nitrate (16 per cent), 1⅞ pounds; dried blood, ¾ pound; muriate of potash, ¼ pound; superphosphate, ¾ pound; 4–12–4, 3 pounds; ground limestone, 5 pounds. These various fertilizers were applied in equal quantity and at the same time to each plot. A moderate state of fertility was maintained as indicated by rapid soil tests. No attempt was made to maintain similar fertilizer levels in each plot.

The plants were pinched several times following planting. No further pinching was done except in the spring when the vigorous blind shoots were cut off. In the summer of 1940 the plants were slightly dried and lightly cut back by July 16. In the season of 1940–1941 no drying of the plants was done, but the plants were gradually cut back as flowers were cut during March, April, and May.

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Records were kept of the number of flowers cut, weight of flowers and stem in grams, stem length in inches and weight in grams of all other wood removed. This latter item included "hooks", prunings, and blind wood removed. These measurements are summarized in Table I. The period covered for each of the years is as follows: September 12, 1939, date of first cut, to May 31, 1940; June 1, 1940 to May 31, 1941; June 1, 1941 to June 15, 1942.

A study of the results (Table I) shows that the average flower production per plant varied from 24.77 in the half humus, half sand treatment to 21.45 in the half soil, half sand treatment. This represents the 3-year average which includes all flowers cut. The production of flowers has been studied statistically by the analysis of variance method. The value of F for the different treatments was 6.53 with the 1 per cent point 9.78 and the 5 per cent point 4.76 which indicated that the results of this study were significant. A difference of 202.3 flowers per year between treatments is necessary to be significant. On this basis it is seen that the half humus, half sand treatment is significantly better than the other treatments. There is no significant difference in flower production between any of the remaining treatments. It will be observed that there is only a difference of ¾ inch

TABLE I—EFFECT OF SOIL MIXTURES ON THE PRODUCTION AND GROWTH OF BRIARCLIFF ROSES

Treatment	½ Humus ½ Sand	¼ Humus ¼ Soil ½ Sand	⅛ Humus ⅜ Soil ½ Sand	½ Soil ½ Sand
Green weight of all wood cut (grams)				
1939–1940	24467.2	20857.3	21413.0	20505.8
1940–1941	51834.9	40709.8	44052.1	46278.0
1941–1942	92769.2	81619.4	82989.6	76776.2
3-year total	169071.3	143186.5	148454.7	143560.0
Green weight of flowering wood (grams)				
1939–1940	24467.2	20857.3	21413.0	20505.8
1940–1941	41533.7	31246.5	32886.1	35056.1
1941–1942	55463.5	48694.0	48538.4	44524.9
3-year total	121464.4	100797.8	102837.5	100086.8
Total number of flowers cut				
1939–1940	2332	2141	2232	2135
1940–1941	4072	3330	3393	3507
1941–1942	5489	4970	4984	4655
3-year total	11893	10441	10609	10297
Average number flowers cut per year	3964.3	3480.3	3536.3	3432.3
Per cent flowers cut less than 8 inches long	13.0	16.4	17.6	17.0
Average number flowers per plant				
1939–1940	14.575	13.38	13.95	13.343
1940–1941	25.45	20.94	21.21	21.92
1941–1942	34.306	31.062	31.15	29.1
3-year average	24.777	21.794	22.103	21.454
Total stem length (inches)				
1939–1940	26015.0	23059.5	22856.75	22739.5
1940–1941	46156.75	35999.5	37411.75	40228.5
1941–1942	62020.5	55105.25	55826.0	51690.5
3-year total	134192.25	114164.25	116094.5	114658.5
Average stem length (inches)				
1939–1940	11.156	10.77	10.24	10.647
1940–1941	11.335	10.81	11.02	11.47
1941–1942	11.29	11.09	11.20	11.10
3-year average	11.261	10.49	10.82	11.072

between the average stem length of the best and the poorest. No attempt was made to increase the stem length by pinching. This rather uniform stem length between treatments has been observed in previous trials. The half humus, half sand plot has the lowest percentage (13 per cent) of flowers less than 8 inches long. The growth of the plants was greatest in this treatment as is shown by the weight of the flowers cut and the total green weight which includes all material cut. This larger growth was also evident by general observation of plants during the course of the experiment. No observations of the root systems were made since the plants are being carried on in growth for another year. The more favorable growth in the half humus, half sand plots may be due to a more uniform moisture content and aeration. This mixture was loose and rather spongy and if packed together in the hand would fall apart when pressure was released. The other mixtures were more solid and yet had a loose texture. All of the mixtures drained well and were given approximately the same number of waterings.

It may be recommended on the basis of this study that a large percentage of humus is desirable for the greatest production of flowers of the rose Briarcliff under glass. A mixture of one-half humus, one-half sand, when given a treatment similar to that ordinarily accorded to a soil or soil mixture produced a greater number of flowers per plant and with longer stem length. Humus of the type used in this study to be effective in a heavy clay soil such as the Hagerstown silty clay should be used in large proportion. These results seem to confirm similar ones secured in previous studies.

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The Lime and Acid Tolerance of the Common Lilac in New Hampshire Soils

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RECOMMENDATIONS concerning the lime requirements and the soil acidity tolerance of the common lilac *Syringa vulgaris* L., which are found in the literature and in the statements from plantsmen, indicate that the authors are at variance with one another concerning these requirements. The majority state that lilacs will do better when there is an abundance of lime available in the soil. Others maintain that lilacs do not require lime.

According to McKelvey (5) the native habitat of *Syringa vulgaris* L. is confined to the Balkan peninsula, southeastern Europe, in the mountainous portions of the countries of Rumania, Jugo-Slavia, Bulgaria and Greece; a region possessing limestone rock. Anderson (1) states that he has observed the common lilac growing among limestone rocks in this region.

Lilacs thrive in a well-limed soil and are also tolerant of a slightly acid soil according to Harding (3). Free (2) states that lilacs are quite tolerant of soil acidity, but prefer soil with plenty of lime. The fact that lilacs thrive on the "sour-soils" of New England is given as evidence by Wister (8) that lilacs can grow without lime, though he states that soil in a region of natural limestone is the best for lilac culture. Wyman (9) states that lilacs do not need lime except in very acid soils. McFarland (4) gives as evidence that lilacs do not require lime, the fact that lilac bushes have grown vigorously in an acid soil along with ericaceous plants. It is evident that these writers consider soil acidity and lime content to be negatively correlated. The writers did not present data in these papers in support of their conclusions.

Since some of the oldest lilac plantings in America are to be found in New Hampshire (McKelvey (5)) and since plantings are to be found throughout the state, a survey was undertaken to determine the constituents of the soils upon which established clumps of common lilacs were growing.

Observations were made by the writer and soil samples were taken from 46 lilac clumps, representative of the entire region of New Hampshire where common lilacs are grown. The samples were most frequently taken from clumps adjacent to old cellar holes or near foundations of houses. In all cases the plants selected were in good health and normal vigor. The soil was removed from the area immediately adjacent to the feeding roots. The samples were purposely taken from old clumps which had had no immediate care, fertilizing or cultivating, in order to determine the acidity range and its relation to the available magnesium and calcium in these soils. These samples were analyzed by the Agricultural Chemistry Department of the University of New Hampshire. The analysis used was a modification of the "Universal" method of chemical soil analysis perfected by Morgan (6).

The usual pH range on unlimed cultivated fields of New Hampshire according to the Agricultural Chemistry Department is pH 4.8 to 5.5. The data (Fig. 1) show that the lilac soils range from pH 4.4 to 7.7. Spurway (7) reports the optimum pH range, with other soil conditions favorable, for *Syringa vulgaris* L. is pH 6.0 to 7.5. Fig. 1 shows that 20 samples or 43.5 per cent of those examined come within this range. One sample is above this range and 25 samples or 54.3 per cent of those examined are below this range.

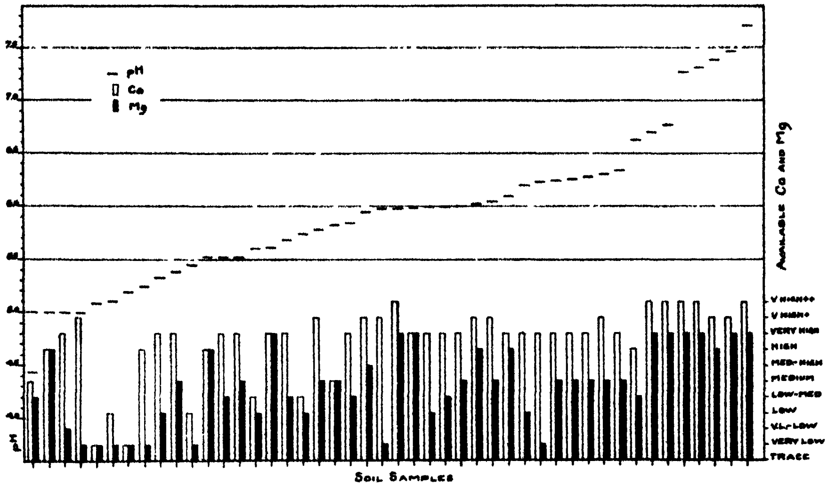

FIG. 1. The pH values and the available calcium and magnesium of the soils.

There is a wide range in the amounts of available calcium and magnesium in these soils (Fig. 1). As is to be expected for the high pH values, there is a correspondingly high available calcium and magnesium content. Within the low pH range, 4.4 to 5.8 the amount of available calcium and magnesium shows great variation. From a pH of 5.3 and upward the available calcium is greater than the available magnesium in these soils; and the amounts of both of these follow the same upward trend as that of the pH range. The available calcium and magnesium of these soils are above the usual range for undisturbed soils of this region. This greater amount of available calcium and magnesium in these samples might be attributed in part to the cumulative effect resulting from the common practice of applying wood ashes to the shrub plantings, lawns and gardens. Plaster lime and in some cases brick mortar next to the foundation walls, may have also added to the soil constituents.

From the above, it may be concluded that, the common lilac in New Hampshire is tolerant of a wide range of soil acidity. Furthermore, these results tend to indicate that lime is available to lilac plants even in soils of high acidity in New Hampshire. This is in agreement with the opinion of the majority of lilac authorities that a lime supply is desirable for the better growth and continued vigor of lilac plants.

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Nitrogen, Phosphorus and Potassium Content of a Silt Loam Soil Following Ten Years of Surface Applications of Commercial Fertilizers

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LITTLE information is available regarding the actual penetration of nitrogen, phosphorus and potassium in soils following surface applications of commercial fertilizers. Nitrogen, being in true solution, moves throughout the soil with the soil water. Soil texture, rainfall and other factors influence the rate of its movement. Phosphorus and potassium are considered to move much more slowly in the soil because they are absorbed on the surface of soil particles. Penetration of phosphorus is considered to be very slow, showing a downward movement of an inch or less a year.

PROCEDURE AND METHODS

Work was undertaken in the spring and fall of 1942 to give further information on the amount and penetration of nitrogen, phosphorus and potassium in soils following surface applications.

In 1931 fertilizer tests were started with 500 Moline elms planted in a silt loam soil (1). The area occupied by this plantation had previously been in alfalfa sod. Complete fertilizers, 12–6–4 and 6–8–4 and ammonium sulfate (20 per cent) and Ammo-phos (11–48–0) were applied to different plots in the fall, spring, and summer. For the first five years of the experiment, applications were made on the basis of adding ¼ pound of available nitrogen per each inch in diameter of the tree 2 feet above the soil. During the second five years of the test the application was increased to ½ pound of available nitrogen per each inch in diameter. The fertilizer was spread over the surface of the whole area occupied by the tree roots. During the early years of the test the fertilizer was cultivated in, later it was left on the surface, only the weeds being cut. The trees were approximately a half inch in diameter when they were planted and were 5 to 6 inches in diameter in 1942.

To determine the nitrogen, phosphorus and potassium content, 10 soil cores were taken at random from each of the fall fertilized plots in May, 1942. Ten cores were taken from the check plot and three additional cores from each of the fall fertilized plots in November, 1942. Each core was taken 24 inches deep and divided into inch segments. Samples were dried for at least 10 days at room temperature before testing. Tests were made on each inch segment for nitrogen, phosphorus and potassium and on each segment for at least half of the cores for pH, with the exception of the check plot. Soil tests were made colorimetrically, as developed by Spurway (2). The pH was determined by the Soiltex method. Some cores were checked in duplicate with a potentiometer.

Data taken from the Meteorological Summary, Weather Bureau, United States Chamber of Commerce, for Columbus, show that 15.93 inches of rain fell between October 1, 1941, and April 30, 1942. This was 3.65 inches below normal for this period. There were heavy rains in October, 1941, following application of the fertilizer, resulting in an excess, above normal, for October of 2.20 inches. Rainfall was below normal for all other months between October, 1941, and May, 1942. Rainfall for the period of May 1, 1942, to October 31, 1942, was 15.79 inches, a deficiency of 2.70 inches below normal. Only the month of September, 1942, showed normal rainfall for this period.

RESULTS

Data are presented in Tables I and II. Figures given in Table I are the averages of 10 cores. Figures given for the check plot are the averages for 10 cores, while the other figures given in Table II are averages for three cores.

TABLE I—pH, NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF SOIL SAMPLES (CORES TAKEN MAY, 1942)

Core Segments (Inch Depths)	pH				Nitrogen (Ppm)				Phosphorus (Ppm)				Potassium (Ppm)			
	12–6–4	6–8–4	NH_4SO_4	Ammo-phos	12–6–4	6–8–4	NH_4SO_4	Ammo-phos	12–6–4	6–8–4	NH_4SO_4	Ammo-phos	12–6–4	6–8–4	NH_4SO_4	Ammo-phos
1	4.9	5.8	4.6	5.6	40.6	26.1	18.9	11.2	19.5	22.4	0.4	6.3	7.0	18.0	5.0	12.5
2	4.6	5.4	4.5	5.2	21.7	13.7	9.1	8.3	4.5	11.1	0.1	6.0	3.2	21.8	4.5	7.3
3	4.6	5.2	4.2	5.0	23.0	14.5	6.8	8.1	2.2	6.6	0.0	6.0	2.3	19.3	3.0	3.0
4	4.5	5.1	4.2	4.9	24.0	18.6	8.7	8.9	1.0	2.6	0.0	6.5	2.7	15.0	3.0	0.0
5	4.9	5.0	4.2	4.6	27.3	19.1	12.5	9.5	1.3	2.7	0.0	4.8	3.0	11.1	1.0	0.0
6	5.4	5.0	4.4	5.6	25.8	19.5	14.0	10.3	0.6	1.1	0.0	4.1	1.5	7.9	0.5	0.0
7	5.6	5.2	4.7	6.2	25.5	20.3	22.0	12.5	0.6	0.7	0.0	3.3	0.5	4.6	0.0	0.0
8	5.9	5.4	4.8	6.2	29.0	20.9	25.5	16.2	0.5	0.4	0.0	2.2	0.5	2.9	0.0	0.0
9	6.0	5.0	5.2	6.2	32.8	22.0	26.5	18.7	0.3	0.4	0.0	1.9	0.3	1.3	0.0	0.0
10	6.0	5.2	5.6	6.2	33.0	21.1	30.5	20.8	0.1	0.3	0.0	0.9	0.3	1.0	0.0	0.0
11	6.1	5.4	6.0	6.2	37.5	21.0	34.0	25.0	0.1	0.2	0.0	0.4	0.0	0.3	0.0	0.0
12	6.0	5.4	6.0	6.1	34.5	27.0	35.0	29.5	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
13	6.1	5.5	6.1	6.2	40.0	29.3	35.0	29.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
14	6.1	6.2	6.1	6.2	42.5	33.8	37.4	35.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
15	6.2	6.4	6.1	6.2	41.5	38.3	45.0	36.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6.2	6.5	6.2	6.2	42.0	39.8	48.5	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	6.4	6.5	6.2	6.2	38.5	15.0	45.0	48.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	6.5	6.5	6.4	6.4	49.5	53.3	48.9	56.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	6.4	6.9	6.4	6.3	49.5	52.3	55.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	6.5	6.9	6.5	6.4	42.0	56.3	55.0	56.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
21	6.5	6.9	6.5	6.4	42.5	60.3	55.0	57.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	6.6	6.9	6.5	6.3	43.0	63.0	55.0	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	6.6	7.1	6.7	6.4	40.0	68.0	55.0	68.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	6.8	7.2	6.7	6.4	46.0	61.8	58.8	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Since the fertilizer applications were calculated to apply the same amount of nitrogen regardless of the carrier, it might be expected that the nitrate nitrogen content would be relatively uniform in the different plots. Such, however, is only partially true. If the May analyses figures are plotted, it is apparent that the curves are relatively uniform. The nitrate nitrogen content is medium to relatively high in the first inch, drops to its lowest point in the second or third inch and then increases, with some variation, to the 24-inch depth. The curves for the 6–8–4, ammonium sulfate and Ammo-phos are especially uniform. The nitrate

TABLE II—pH, NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF SOIL SAMPLES (CORES TAKEN NOVEMBER, 1942)

Core Segments (Inch Depths)	pH					Nitrogen (Ppm)					Phosphorus (Ppm)					Potassium (Ppm)				
	Check	12–6–4	6–8–4	NH$_4$SO$_4$	Ammo-phos	Check	12–6–4	6–8–4	NH$_4$SO$_4$	Ammo-phos	Check	12–6–4	6–8–4	NH$_4$SO$_4$	Ammo-phos	Check	12–6–4	6–8–4	NH$_4$SO$_4$	Ammo-phos
1	6.2	5.7	6.0	4.8	4.5	1.7	4.0	3.3	10.0	10.0	0.5	3.1	2.8	0.0	2.5	1.5	1.7	1.7	0.0	0.0
2	—	—	—	4.3	4.5	0.9	12.3	11.7	11.7	10.0	0.3	1.7	2.0	0.0	2.5	0.5	0.5	1.7	0.0	0.0
3	—	—	—	—	4.5	0.9	35.0	16.7	12.3	14.0	0.2	0.7	1.0	0.0	2.2	0.0	0.0	1.7	0.0	0.0
4	6.2	4.8	5.5	—	4.0	1.2	50.0	21.7	13.3	23.3	0.2	0.7	1.0	0.0	1.9	0.0	0.0	0.8	0.0	0.0
5	—	—	—	—	4.8	1.0	50.0	26.7	2.3	28.3	0.2	0.5	0.8	0.0	2.2	0.0	0.0	0.0	0.0	0.0
6	—	—	—	—	5.3	0 6	46.7	45.0	3.0	25.0	0.1	0.3	0.8	0.0	1.9	0.0	0.0	0.0	0.0	0.0
7	—	—	—	4.8	—	0.9	46.7	50.0	21.7	36.7	0.1	0.2	1.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0
8	6.3	5.8	5.7	5.0	—	0.6	45.0	41.7	20.0	18.3	0.1	0.0	0.3	0.0	1.2	0.0	0.0	0.0	0.0	0.0
9	—	—	—	—	6.5	0.1	25.0	50.0	21.7	10.0	0.0	0.0	0.0	0.0	1.2	0 0	0.0	0.0	0.0	0.0
10	—	—	—	—	6.5	0.1	23.3	58.3	33.3	10.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
11	—	—	—	—	—	0.2	23.3	53.3	33.3	10.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
12	6.4	6.4	6.3	6.3	—	0.1	26.7	41.7	25.0	13.3	0 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	—	—	—	6.3	—	0.2	20.0	33.3	33.3	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	—	—	—	—	—	0.2	30.0	26.7	33 3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	—	—	—	—	—	0.2	38.3	33.3	18.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6.3	6.8	6.5	—	—	0.2	33.3	41.7	25.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0
17	—	—	—	—	—	0.2	38 3	25.0	21.7	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	—	—	—	6.5	6.5	0.2	32.7	20.0	20.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	—	—	—	6.7	6.5	0.2	33.3	31.7	25.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0
20	6.3	6.6	6.5	—	—	0.2	50.0	30.0	28.3	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	—	—	—	—	6.5	0.3	36.7	25.0	14 0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	—	—	—	—	6.5	0.3	40.0	23.3	25.7	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	—	—	—	6 5	—	0 3	33.3	33.3	15.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	6.2	6.5	6.5	6.5	—	0.5	41.7	30 0	17.3	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

nitrogen content of the 12–6–4 plot was the most uniform throughout the 24-inch depth. It might be mentioned that trees in this plot show slightly better growth than those in any other plots.

Data for nitrate nitrogen content of the cores taken in November show considerable variation from those taken in May. The curves for the different plots follow the same general pattern but show more variation. The November cores did not show the high content in the initial inch and then the drop to the second and third segments. They start low and increase relatively rapidly to the high point, occurring between the fourth and tenth segments in most cases. Another high point in nitrate nitrogen level in the 12–6–4 plot occurred at the 20-inch level. In most cores, from all plots, there was a leveling-off of the nitrate nitrogen content from the tenth or fourteenth to the twenty-fourth segment. The increased nitrate nitrogen content in the fourth to tenth segments in the November cores can be partially explained on the basis of leaching of the nitrate nitrogen from the initial segment to lower levels during the summer months. The lower content of nitrate nitrogen in the deeper segments, in the November cores as compared with the May cores, is more difficult to explain. There could be some leaching from these depths but the C horizon, reached at the 20- to 25-inch level, is a heavy, poorly drained, silty clay loam which would not be favorable for this process. Some of the nitrate nitrogen was undoubtedly absorbed by the tree roots but this absorption should be greatest in the surface 12 inches. Root studies (1) in 1937–38 showed that 17 to 47 per cent of the roots were in the upper 6 inches, 48 to 86 per cent in the upper 12 inches, and 79 to 98 per cent in the upper 18 inches.

Spurway (2) considers 2 parts per million of nitrate nitrogen as low, 5 to 10 parts per million as medium and 25 parts per million as high. The data in Table I show that no tests were below the medium level. Twenty-one of the 24 segments of the 12–6–4 cores averaged from 25–50 parts per million of nitrate nitrogen. No segments showed more than 50 parts per million. The cores from the other plots showed the following results: 6–8–4, 8 segments averaged 25–50 parts per million of nitrate nitrogen and seven segments showed over 50 parts per million; ammonium sulfate, 11 segments averaged 25 to 50 parts per million and six showed over 50 parts per million; and Ammo-phos, seven segments averaged 25 to 50 parts per million and six showed over 50 parts per million. Over 50 parts per million of nitrate nitrogen might cause some injury to the roots. It will be noticed, however, that these high concentrations were in the lower levels, occupied by a small percentage of roots. The nitrate nitrogen content in the cores from the check plot were low, even absent in many segments of individual cores.

As previously stated, the different fertilizers were applied at a rate to give an equal amount of nitrogen in each case. This varied the amount of phosphorus applied. The 6–8–4, as applied, added two and one-half times as much phosphorus as the 12–6–4. Ammo-phos, as applied, added three and one-half times as much phosphorus as the 6–8–4 and nine times the amount added in the 12–6–4.

The tests for phosphorus in the cores from the 12–6–4 and the 6–8–4 plots are similar as shown by the figures in Table I. The phosphorus content is very high in the initial inch, drops sharply in the second inch, but is still high, and then drops to a medium to low content in lower segments. No test for phosphorus was obtained below 14 inches. The larger amounts of phosphorus applied with the 6–8–4 fertilizer was manifest by a noticeably higher content in the first three segments, a medium content to 6 inches, and penetration to greater depths than shown in cores from the 12–6–4 plot.

Although considerably more phosphorus was applied with the Ammo-phos fertilizer than either the 12–6–4 or the 6–8–4, the analyses showed only approximately one-fourth to one-third as much in the initial inch. Based on Spurway's (2) statements of medium and high phosphorus, the cores from the Ammo-phos plot showed high phosphorus in the upper 5 to 6 inches, with medium amounts down to 9 to 10 inches. This is twice the depth of favorable penetration of phosphorus shown by any other plots.

The cores taken in November showed similar trends in phosphorus content but lower amounts in practically all segments.

The more favorable penetration of phosphorus in the Ammo-phos and the 6–8–4 plots has not resulted in better growth of the trees in these plots. Data on growth rates over the 10-year period show little difference between the 12–6–4, 6–8–4 and Ammo-phos plots. They are slightly best in the order given. The shallow root system of the trees in the 6–8–4 plot (2) and the lack of potassium in the Ammo-phos fertilizer and the high acidity in this plot may be one answer to the slightly poorer growth of these trees.

Analysis of potassium in cores taken in May showed a rather low content in all segments except the initial one in the 12–6–4 plot and the first seven segments in cores from the 6–8–4 plot. The potassium content was high in the first four segments and medium in the next three segments of the 6–8–4 plot cores. Small amounts of potassium were found in the first few segments of cores from the ammonium sulfate and Ammo-phos plots. The higher amounts of potassium in cores from the 6–8–4 plot can be explained on the greater amount of potassium applied to this plot. Tests showed very small amounts of potassium in all cores taken in November.

Data for pH show a relatively uniform reaction, especially in segments below 12 inches. Cores taken in both May and November showed a relatively low pH in those from the 12–6–4, ammonium sulfate and Ammo-phos plots, particularly in the first few segments.

SUMMARY AND CONCLUSIONS

Data are presented relative to pH and content of nitrate nitrogen, phosphorus and potassium in soil cores, divided into 24-inch segments, taken from plots to which a 12–6–4, 6–8–4, ammonium sulfate and Ammo-phos fertilizers had been applied yearly over a 10-year period.

Segments of all cores taken in May showed medium to very high contents (70 parts per million) of nitrate nitrogen. The general trend of the analyses of these cores was a medium to relatively high content in the initial segment, dropping to the lowest content in the second and third segments and then gradually increasing to the high content at the 24-inch level. The nitrate nitrogen content was the most uniform in the cores taken from the 12–6–4 plot.

No test for phosphorus was found below 14 inches except a small amount in one 20-inch segment of a core taken from the Ammo-phos plot. The amount and depth of penetration of phosphorus depended in some cases on the amount of phosphorus applied. Heavier applications gave greater amounts at deeper levels. Analysis of cores from the Ammo-phos plot showed smaller amounts of phosphorus in the initial segment, but twice the depth of penetration of amounts favorable to growth, to 10 inches, when compared with analyses of cores from the 12–6–4 and 6–8–4 plots. This adds weight to the thought often expressed that phosphorus applied in Ammo-phos shows greater and more rapid penetration than when applied in other carriers.

Analyses showed no potassium below the 11-inch segment in any of the cores. The amount and depth of penetration of potassium, again, seemed to depend on the amount of application. Favorable amounts of potassium seemed to be limited to the upper 5 to 7 inches, even in cores taken from plots receiving applications of a complete fertilizer.

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Some Responses of Trees in a Few Subtropical, Evergreen Species to Severe Pruning

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OBSERVATION of trees in California gives at least a strong suggestion that the response of some broad-leafed, evergreen trees to severe pruning, before the spring period of rapid growth, is not in all ways like that of temperate-zone, deciduous trees. Pruning deciduous trees severely in winter, or before much growth has been made in spring, causes new shoots to continue succulent growth later in summer and to become larger and thicker than shoots on unpruned trees, although total growth on the tree is reduced owing to the reduced number of leafy shoots. On some evergreen trees succulent growth is not prolonged as much by equally severe pruning as on deciduous trees (1). On others it is prolonged more. Even on trees that are succulent after such a pruning longer than are deciduous trees, actual enlargement of the shoots is much slower. For example, a tree of *Eugenia paniculata* var. *australis* Bailey more than 15 feet tall was broken off at the ground by wind; a sprout from the stump grew succulently all summer but did not become 2 feet tall in a year, made little if any more growth than such a sprout on a much smaller Eugenia stump would have made and not 25 per cent of the growth an apple or a peach stump supported by such a root system would have made. Apparently the large root system for one shoot did not increase the rate of shoot elongation although it caused prolonged succulence. Probably the large root system supplied the Eugenia sprout with enough water and mineral nutrients for prolonged, succulent growth but did not contain enough of stored carbohydrates or of some other organic substance for as rapid elongation of the shoot and development of leaves in the first spring after loss of its leafy top as a richly stored apple or peach root system would support.

In fact, respiration and a little growth in a root system that contains very little stored food may, possibly, deplete the small food supply from a very small leaf surface on such a severely pruned non-storing tree. In 1935 a number of deciduous trees and subtropical, evergreen trees were planted for a study of this possibility and also for a study of the possibility that the very severe pruning often given in training young street trees may retard the growth of subtropical evergreens more than of deciduous, temperate zone trees. In this last study some trees had the lower branches removed nearly to the apical shoot each year, as many young street trees have in practice in some cities, while others had most of these lower branches left until the permanent head began to form, except that the upward-growing part of each temporary branch was cut back.

Deciduous trees (*Platanus acerifolia* Willd. and *Fraxinus velutina* Torr.) pruned by the former method increased in height a little faster and in trunk circumference at the base considerably slower than those pruned by the latter method, while evergreen trees pruned by the former method increased in height considerably slower and in trunk circumference very much slower than trees pruned by the latter method. Fig. 1 shows a typical camphor tree *Cinnamomum Camphora* Nees and Eberm. pruned each way as they appeared by the autumn of 1938. The camera lens was the same distance from the base of each tree. The increase in size caused by the less severe pruning

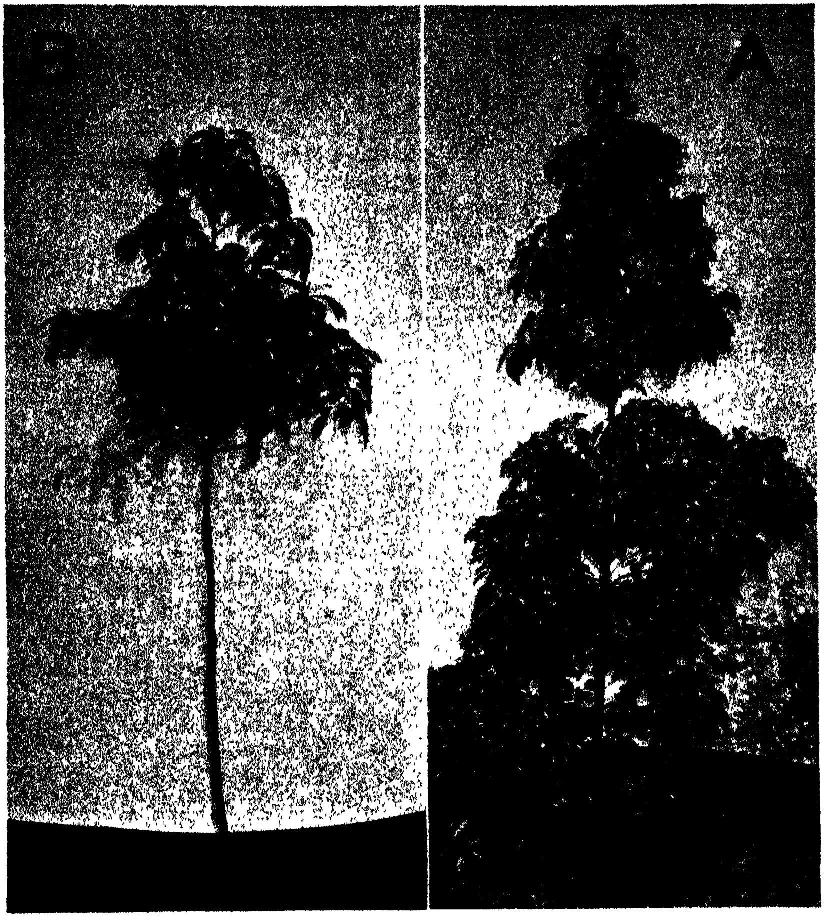

FIG. 1. Camphor trees, B pruned more severely than A from the time when it was less than 2 feet tall.

was greater than this on trees of *Prunus Lyoni* Sarg. and slightly less on trees of *Quercus agrifolia* Née. and *Ulmus parvifolia* Jacq. In all four of these species pruning by the latter method, shortening down the lower branches and delaying their complete removal as long as possible, caused the trees to stand erect without stakes two years or more sooner than trees pruned as soon as possible.

Early in 1940 announcement was made that the land on which these trees were growing would soon be sold. Since these studies could not be completed, the trees were used for a simple study of response to very severe pruning, cutting away all the top. Dry weight of these tops was determined. The sprouts that grew from the stumps during the following summer were also cut off and their dry weights, excluding leaves, determined. In Table I the dry weights of these 1940 sprouts are given as per cent of the dry weights of the tops that had been cut off in the spring before the sprouts grew. Dry weights of the top of a tree should be a reasonably accurate measure of the size of the root system left in the ground to supply water and nutrients and stored food to sprouts from the stump. The leaves were counted on trees of some species before the tops were cut off and on the sprouts that grew from the stumps, but the number of leaves or the leaf area on a deciduous tree can hardly be compared with that on an evergreen tree; for on an evergreen tree so many of the leaves may be more than a year old and in varying degrees of senility.

In Table I, the species are arranged, if my observations are dependable, so that those with the shortest summer growing period (those farthest from being evergreen) are above those that have more nearly continuous growth and succulence, when the weather is warm enough.

TABLE I—Dry Weight of Stump Sprouts Grown in One Summer as Per Cent of Tops Removed in the Preceding Winter

Species	Number of Trees	Sprouts as Per Cent of Top That Was Cut Off	Leaves of Sprouts as Per Cent of the Number Borne by the Top in the Preceding Year
Pistacia chinensis	6	31	65
Platanus acerifolia	10	46	67
Koelreutaria paniculata	5	27	—
Fraxinus velutina	18	48	105
Pterocarya sp.	4	51	—
Liquidambar Styraciflua	6	28	91
Ficus carica	10	52	—
Quercus agrifolia	6	28	29
Ulmus parvifolia	4	12.5	—
Ceratonia Siliqua	12	11	54
Cinnamomum Camphora	8	17	54

With the possible exception of the nearly deciduous *Quercus agrifolia,* stumps of evergreen species made less growth in proportion to the size of tops that had been cut off than stumps of deciduous species. There is one large source of error in this table: the larger the top that is cut off, the smaller the stump sprouts will be in proportion. *Ulmus parvifolia* stumps, for example, made much sprout growth but little in proportion to the heavy tops. Fig. 2 is prepared to show the relation of the original size of a tree top to the per cent of its weight in sprouts its stump can produce in a year.

With rather few individual exceptions, stumps of deciduous trees made more growth than stumps of evergreen trees of approximately the same size. Loss of the land and consequent sudden discontinuance of the project prevented chemical studies to learn whether the deciduous tree roots contain in each winter a greater supply of carbohydrates than roots of these evergreen species and whether this is the

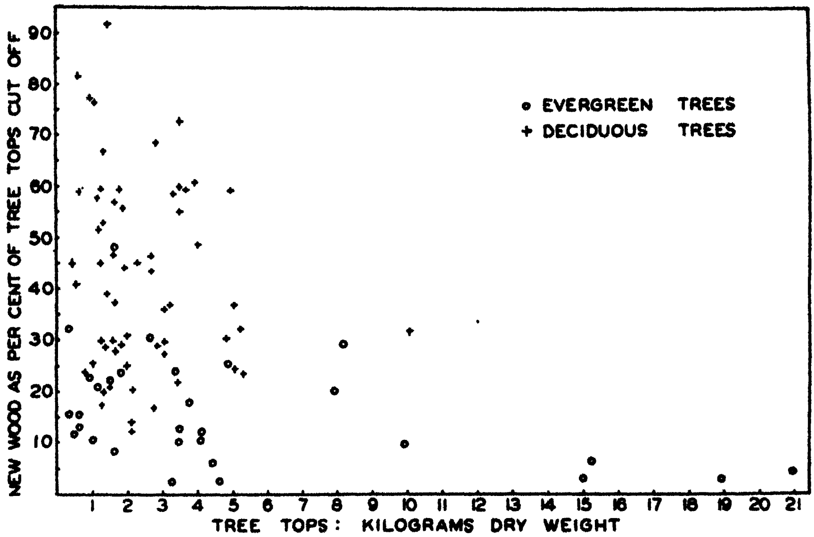

FIG. 2. Effect of the size of tree tops cut back to near the ground on the per cent of their dry weight made in shoot growth from their stumps in the following summer.

probable explanation of the greater shoot growth in response to such severe pruning.

SOME EUCALYPTUS SPECIES

When trees of deciduous species are pruned severely any time between early autumn and the beginning of spring growth, whether the pruning is a cutting back or a thinning out of branches, many watersprouts are apt to grow from dormant buds along the branches. Trees of some Eucalyptus species tend to make very little watersprout growth in response to the most severe cutting out of lateral branches if the terminal shoots of the main branches are left intact. On the campus of the University of California at Los Angeles, 127 trees of *Eucalyptus viminalis* Labill. had large numbers of lateral branches cut out during 1940–41 and then, in the spring of 1942, had some of the main branches cut back, usually to a downward swinging lateral branch. On June 1, 1942, all these trees were examined carefully for the presence of watersprouts. Nearly all that were found were on stubs of main branches left projecting beyond a lateral branch, or on the side of a main branch opposite a drooping lateral to which it was cut: number of trees on which watersprouts were found on projecting stubs = 25; number on which watersprouts were found opposite a drooping lateral to which a main branch had been cut = 47; number on which watersprouts were found elsewhere = 9; number on which no watersprouts were found = 68. The watersprouts were usually on one branch that constituted only a very small part of the tree. If main branches instead of trees had been counted, the percentage without watersprouts would have been much larger.

In 1941, late in December, 32 trees of *Eucalyptus globulus* Labill. about 50 to 65 feet tall in a hedge, each tree with a strong central leader and rather short spreading or drooping branches, were cut back to about 30 feet in height. Adjacent to each of these trees was one, to be taken out later, which was cut back to the same height but had also all the main branches cut off. By February, 1942, about 2 months after the pruning, sprouts were beginning to show on the old bark of these trunks. A month earlier, rapid new shoot elongation was showing on the branches that were left. On May 28, 1942, the average number of watersprouts on tree trunks with a few branches left was 51, and the average number on trees with no branches left was 107. Clearly the leafy branches inhibited growth of watersprouts from dormant buds on the trunks. There was some tendency for trees with the largest branch system left to have the smallest number of watersprouts. Leaves on the tree just after pruning were counted as a measure of the size of the branch system left: 8 trees with 300 to 600 leaves left at pruning averaged 35 watersprouts each; 10 trees with 25 to 200 leaves averaged 71 watersprouts each. Some of the trees with the largest number of leaves left at pruning, however, had also among the largest numbers of watersprouts. This was usually when the part of the trunk above the uppermost branch was long or when the branches were all on one side of the trunk; watersprouts form readily on a stub above the branches and on a side of the trunk without branches but not on the part of the trunk directly below a branch.

Reasoning from the failure of branch removal to cause watersprout growth on *Eucalyptus viminalis,* and from frequent failure of shoots to grow on branch stubs on some evergreen species such as *Leptospernum laevigatum* F. Muell., I thought at the beginning of this experiment with *E. globulus* that, because evergreen trees have leaves throughout the year to evaporate water, turgidity in the tissue might be too low most of the time to stimulate growth of dormant buds in the old wood. However, a water deficit in any part of the tree causes rapid movement into that part so that the deficit tends to be nearly uniform in all parts; therefore, if low turgidity should be the inhibiting influence on growth of dormant buds, those on the part of the trunk above the branches and on the side of the trunk opposite a branch should be inhibited as strongly as any. Some substance or influence must move downward from leafy branches of Eucalyptus trees and inhibit growth of dormant buds in the parts of the old branches and the trunk that have direct phloem connection with the leafy branch parts. If the inhibition was by an auxin it may have come from the new leaves that were forming before the growth of the dormant bud meristem in the old bark began. Counting of the old leaves merely supplied a rough measure of the probable growth of new leafy extensions of shoots left on the tree at pruning.

Leafy branch apexes inhibit watersprout growth in response to severe thinning out of branches on some other Eucalyptus species, also, such as *Eucalyptus robusta* Sm. and *E. maculata* var. *citriodora* Bailey.

Eucalyptus globulus, E. viminalis, and *E. robusta* trees have been observed to form adventitious shoots from callus between the bark and the wood at wounds, but rarely except when the pruning is so severe that few dormant buds are left near the wound. Such adventitious shoots rarely grow at the end of a branch stub; and so this ability to form adventitious shoots from callus is not great enough to be of importance in covering the ends of stubs and preventing them from rotting.

When trees of this Eucalyptus species are about to become too tall or the branches long and dangerous with all growth on the ends, the location of new branches can be regulated by leaving stubs to grow watersprouts.

SUMMARY

Trees of at least some subtropical evergreen species make slower growth in response to severe winter pruning than deciduous trees make; forced discontinuance of the experiment prevented study of the cause of the difference in response. These data do not necessarily suggest the conclusion that much less severe pruning would dwarf trees of these evergreen species more than deciduous trees.

Trees of certain Eucalyptus species, if not of most, will rarely make shoot growth from dormant bud meristem in bark that is directly connected with leafy distal shoots, even in response to very severe cutting of lateral branches from main branches; such pruning will cause strong, much-branched growth in the shoots at the apex of a main branch so that it is in more danger of being broken by the weight of these shoots or by wind. Shoots will grow, however, from stubs beyond the most distal lateral branch left when a main branch is cut back and may grow from the main branch on the side opposite this most distal lateral branch, especially if it is a small drooping one.

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